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SCIENCE AND CIVILIZATION

ESSAYS ARRANGED AND EDITED

BY

F. S. MARVIN

AUTHOR OF 'THE LIVING PAST', 'THE CENTURY OF HOPE', ETC.

'Savoir afin de prévoir.'—AUGUSTE COMTE

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PREFACE

This volume is based on lectures given at the Sixth Unity History School held at Woodbrooke near Birmingham in August 1922.

Preceding volumes having treated of problems connected with the Unity of Mankind rather from the synthetic and general point of view, it was thought well in this course to attempt a more analytical line of approach and to consider in some detail one of the leading threads which have tended progressively to bind humanity together in historic times. Science was obviously the first to select. This volume will, it is hoped, be followed by another dealing with Art from the same point of view. The lectures for it are to be given in Vienna in the coming August.

The editor and readers of this book are under a debt to Dr. Charles Singer which can hardly be overstated. Those who attended the course will remember the vigour and the learning which added so greatly to its success. In seeing the book through the press his generous help and good judgement have been of equal service.

F. S. M.

Berkhamsted,
April 1923.

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THE BEGINNINGS OF SCIENCE

J. L. Myres

In further instancing the case of the King of Benin, the Consul General stated that the King, when coming down from the City during the rains, said the white man did not know how to stop the rain, but that, if he (the King) wanted to stop it, he would send down to the river, bring a man from there, and hang him up on the crucifixion trees. The Consul explained to the Chiefs how wrong and silly such a notion was, and said it would never be allowed by the British.—[Report of a Palaver at Brass, W. Africa : *Standard*, 8 November 1897.]

It is an observation as old as Thucydides, that we may learn something about early stages of an advanced culture from the present-day practices of savagery. It is less commonly realized how much the practices of primitive savagery have to tell us about the less advanced elements in a present-day society which is for the most part civilized. We speak of primitive 'cultures'; and, therein, of arts or crafts, and other expressions of primitive personality, amazingly advanced in technique and aesthetic value; yet alongside of these modes of self-expression, so rationally responsive to daily needs of humanity, such 'cultures' exhibit instances of an almost incredible stupidity—as it seems to us—and of intolerable, almost inhuman self-repression, all the more surprising from their association with such intimate interplay of hand and tongue with brain, such orderly, intelligible—in a word, reasonable—accommodation of effort to need. I dealt briefly with this paradox in a contribution to the first of these conferences,[1] and need only repeat the

[1] *The Unity of Western Civilization*, 1915, pp. 41–5.

conclusion, which then seemed to me probable, that the most charitable, most just, and most illuminating assumption is that here and there man has just 'lost his way' intellectually; has in fact 'stopped thinking'; and that the reasons for such temporary inhibition of his reasoning faculties are in the main these two, Fear and Pride—defect, namely, and excess of self-reliance—with the result that, as Heraclitus expressed it long ago, 'though reason is common to all, most men live as if they had a way of thinking of their own'. For men in such predicament—whatever be the cause of it—popular language has the neatest of phrases; for we say—do we not?—that they have 'lost their heads'; and when a man 'loses his head' there is no limit to the folly and misery that may follow.

I have ventured to suggest that the reasons for such inhibition of man's reasoning are mainly two, Fear and Pride; and this would seem to be the place to elaborate each of these suggestions, before going farther.

§ 1. *Fear; the Savage and the Law of the Jungle; 'Panic' in Simple Societies*

Few of those unforeseen contributions to knowledge which have resulted from the European War have been more illuminating to the anthropologist than the revelation on a vast scale of how men behave under the mastery of overwhelming fear. I do not mean the moral fear of the coward, or the intellectual fear of the man who, like Kipling's elephant, 'thinks too much', until the worser part appears the better, and he anticipates the historian's task of demonstrating how (as he argues) we are losing the war, and why (as he assures us) we must lose it. I mean rather that physical fear which may beset the stoutest heart and the clearest head when something

which is neither heart nor head encounters a 'force, not ourselves', intolerably great, incessantly prolonged, unforeseeable, irremediable. For such physical, overmastering, irrational fear of what is limitless, incommensurable with us, unsusceptible of alteration by any act of ours, the Greeks had a name, and, after their manner, a hypothesis, a myth, if not a reasoned explanation. If an army fled when no man pursued; if sheep and shepherd alike were scattered, as I am told that sheep used to be stampeded here during the war; or if merely the mountain goats scampered and vanished, in a great stillness, as I have seen them do on Cretan hills—they called it πανικὸς φόβος; and 'panic fear' has passed from their language into ours. Their explanation, if we may call it so, is in the best vein of their mythology; for panic fear was the act of the great god Pan; and Pan is the anthropomorph of Wild Nature, of all that manless and reasonless world which is Not-Us; the ἄπειρον, the 'limitless', indeterminate congeries of things, which baffled the Greek philosopher; the chaos 'without form and void' of the Hebrew thinker, on which it is the task and glory of God and man alike to impose definition, analysis, explanation, until in the latter end man, like Jehovah, rests from his labours, for he sees that it is 'very good'. Of this Pan, as Herodotus says, 'they have no word to say, what became of him, as soon as he was born'; for he is the son of Hermes, the god at whose bidding all chance things come to pass; a very Lord of Misrule. It is his reeds by the river that make pan-pipe music on a still day; he and his nymphs make a 'going in the tops of the mulberry trees' when nothing else could have stayed the marauding Philistine; his goat-hoof started the plunging boulder where no goat trod; his leery goat-eye and a wisp of a beard we seemed to see where neither man nor goat was when we looked again; his

devilish chuckle out of the wayside cave; his loving care of the lost lambs that we found unharmed after so long, in such a thorn-brake, on such a rat's-foot-hold in the cliff. Such was that Pan whom Pheidippides met face to face on the waste places of Arcadia; and vowed him, conscience-stricken, the sanctuary so long over due; and it was panic fear that achieved the Marathon victory, the Persians 'losing their heads' in amazement at the Athenians' attack.

From what Pan became, in the gracious atmosphere of adolescent Greece, we may form some conception, I think, in the light of our own experience of immeasurable, irresistible devastation in the physical and chemical jungles of modern war, of what mere Nature may have meant for unsophisticated, ingenuous man. Perhaps our own infant bogies—a dark room, the mere density of a window-curtain, the wan smell of a top-lighted attic, the bit of path beyond the yew tree, the first conscious fall on the gravel, when the pebbles all rushed at your face—may serve to complete the picture. And infant man had no strong-handed, even-tempered, knowledgeable nurse; at best an equally panic-haunted mother, and the heavy fist of the 'old man' to knock sense into him.

I have called this the 'Law of the Jungle', because it is in the dense forest régime of the tropical rain-belt that we can best observe what happens when Nature, at her strongest and most aggressive, is confronted with man at his weakest, technologically, socially, individually. Here agriculture and domestication of animals are alike impracticable: man's hand is against everything, no less than everything around is against him. Plants he may rob of their fruit, animals of their young; but only to kill and eat. Débris of dead or killed plants, or of the game he has eaten, are his sole raw-materials; for the wholesome basement of rockery lies deep in festering

humus. It is only in his wholly human ingenuity to find secondary uses for such cast-off remnants of Earth's vesture that he differs from the *bandar-log* and the forest carnivora. Concerted action, even in hunting, is a drawback, if not a danger; it scares the creatures he would kill and eat, and attracts those which would kill and eat him. Beyond an early point, experience is not transmissible; youth has no more to learn from age, and in jungle, age cannot keep up with youth; so society breaks up just when it should most cohere. Even family life hardly outlasts the period of infancy. As the Amazon Indian said to M. Crevaux, 'I had a wife, but I don't know where she is now: the children went off and I lost her; she is hunting somewhere, like me.' Consequently there is no 'collective memory', nor tradition of experience; no premium on foresight or ambition, for a great hoard is a great evil and a great waste of good stuff, since in the jungle all stores rot. 'An Indian who has a knife will not give anything for a second'; and if he has no knife, he has probably nothing that he could give for one, unless perchance he has found rubber, *and not dropped it yet.* For the same reason there is little leisure. To quote Crevaux again, 'Our voyage is a continual struggle for existence. All the time we can spare from mapping and observation is devoted to fishing and hunting'; and the last statement might well have been inverted. 'The one thing needful is the one thing uncertain.' In England, when people meet, they talk about the weather: in Greece, they talk about wealth; in the Amazon forest, exclusively about food. Rigid selection, on these lines, of the best individualists to survive, has resulted in unusual suppression of the social instincts, even the instinct of kind, which very few animals lose. The huge mortality is accentuated by frequent cannibalism; for man is good eating; he is the best of sport,

because he is as clever as you are; and besides, if you bag him, there is one hunter less. The greatest happiness, indeed, is that of the smallest number.

The only inalienable property is individual effort. If two individuals can succeed, in the prime of life, in exerting effort-for-three, they may rear a child; if not, they fail, and it is the child who starves first. There is, however, record that an orphan child has been allowed to haunt a camp, and scramble for offal with the dogs.[1]

Yet there is much testimony that within the group 'the voice with the smile wins'. When it is so easy for an ill-used person to quit, honesty and courtesy are the best policy as long as it is to the common interest (as in matrimony) that the group should hold together. There is testimony also to the contentment of such people: we may conjecture that grousers either go away or pine away. There is extreme contempt for other modes of life, utter inability to adopt other ways. Even the simplest barter hardly rouses interest; not so much because they have nothing to offer, as because there is almost nothing that they need. Like the Fenni of Tacitus, 'they have achieved the hardest thing in the world, to have no use for prayer.'

This, however, is not due to stupidity. Of things which concern them—such as animals, plants, country, and weather—such people are very acute observers, and show great practical ingenuity. The failure, with occasional scandal, of attempts to 'make them work' even at

[1] For the social life of jungle-folk in general, consult the chapter in E. DEMOLINS, *Comment la Route crée le Type social*, Paris, 1905, and A. DE PRÉVILLE, *Sociétés Africaines* (ch. v), Paris, 1894. No assumption is intended here that jungle life is the real Garden of Eden, man's primitive estate: only that in jungle, as travellers know it now, man is at his most defenceless against his surroundings, and presumably thinks and acts according to his powerlessness to alter them.

such a simple business as picking raw rubber off the trees and bringing it in, seems due mainly to their inability to realize that what is asked of them, or offered to them, is of any conceivable use: undebauched by intruders, they do not seem even to get drunk, for like Ingoldsby cherubs 'they haven't *de quoi*'. That the needs of any one else in any way concern them appears as utter folly as that any one else should be concerned with needs of theirs. Their apparent laziness, or enjoyment of leisure, which has deceived some observers, would seem to result partly from real need of physical rest between spasms of activity, like the holiday loafing of a schoolboy; partly from habitual economy of effort; partly from indulgence in reflection, for where such effort is required to understand what is going on—at all events to the point of right response to it—hard thinking and much 'brown study' are as essential and natural as they seem to have been, on occasion, to men like King Alfred and James Watt. Let that philosopher cast the first stone who has never appeared at breakfast without a tie.

Now, *what do such people think about?* Here we are rather in the dark, since we have only their acts to guide us; just as we are about men's mode of life when we have only their implements to go by. 'Evolution', it has been said, 'means, sooner or later, a complete transcendence of one group of interests over another', and we have to unthink a good deal of what chiefly interests ourselves if we are to recover the mental standpoint of simple societies and the substance of their thought. Civilized people's 'thinking', as distinct from mere use of their brains in the daily round of their lives, is concerned mainly with high matters which they do not quite understand yet, but their ignorance of which is beginning to be felt practically as an obstacle to desirable activity. Thinkers among ourselves think, for example, about the

constitution of matter; the nature of force and life; high problems of conduct, of politics, of mental and metaphysical philosophy. But the thinking of the savage, too, is concerned with high matters, too high as yet for him, but of no less practical bearing; with hunger, sickness, rain; with the baffling ways of game, and the behaviour of dogs and womankind; with his own feelings and imaginations; and among them, above all, with his dreams. All these puzzle him and prevent him from living as well as he has it in him to live under his actual conditions. He needs, that is, and apparently strives to achieve, in his thinking, two things mainly; an explanation, intelligible to himself, of what it is that is going on; and direction, how to behave, in presence of this which is going on in Nature and in his own experience as a whole. The explanation is to be a response to impulses of curiosity—that is, to his *need to know*—as vital to his well-being as those of any young animal, or of a modern baby, or researcher; curiosity, most active in modern man during infancy and adolescence, and customarily repressed in most of us; but lifelong whenever it has not been so repressed, and irrepressible, as we know, in idiots, gossips, and men of science. From the need of explanation, that is, comes all pure science, no less than all true poetry. From the need of direction, on the other hand, all applied sciences: for the need of direction stands in similar relation to man's *need-to-do*, his instinct to push, to hustle, to disarrange and rearrange things about him till he has got them arranged as he likes, from which all material arts and technical skill proceed, for the conquest and domestication of intractable Nature; and, no less, all social arts and political skill, for the conquest and domestication—let us say at once the 'civilization'—of no less intractable man. Such thought with a view to action involves foresight, and leads to invention; as

thought with a view to knowledge presumes imagination, and achieves discovery.

In such thought with a view to knowledge, there are two distinct phases: in the first, the mere facts are established by observation, and up to the point where their own natural needs are concerned, quite primitive men are good observers, as we have seen, and may also be good recorders of what they observe. The Bushman drawings and the wonderful naturalism of the old French and Spanish cave-dwellers are ample evidence for this. But mere facts have never taken thinking men very far on the road to knowledge; and the second phase of thought begins when the meaning of the facts is expressed by what the Greeks knew as *hypothesis*, by *supposition*, that is, or in plain English *underpinning*; filling in, beneath and behind the facts, whatever is conceived in imagination as really going on, and presenting these appearances to the observer. Primitive ingenuous man, like the greatest philosophers, is but trying to get beneath the surface, behind the veil of appearance, and to reach reality.

Theories of causation, indeed, are by no means the monopoly of European philosophy; nor is the search after causes confined to what we are pleased to idolize as modern and rational civilization. Great as is the advance in applying our more extensive experience of the order of nature, and vast as is the accumulation of data on which that experience itself rests, it is not clear that recent presentations of the problem of causation show by any means corresponding advance upon the earliest speculations—we can hardly call them conclusions—which have been handed down to us. For an adequate theory of the relation of cause and effect, essential as it is to any considerable advance towards mastery of human circumstances, is no less essential from the first step of

progress onwards; and we shall find reason for the view that, whether explicitly or not—and of course more frequently the latter—uncivilized man does practically employ the same methods of inquiry in his researches into the connexions among phenomena as the trained student of modern philosophy or modern science; and that, in spite of obstructions, drawbacks, and defects of system, which appear to the modern inconceivably great, he has sometimes reached results surprisingly like those of his more favoured successors.

The inquiry is of some importance to us here from more than one point of view. In tracing the emergence of successive, more or less independent centres of speculation in the Greek world, it is obviously of considerable value to be able to outline the traditional beliefs among which the first philosophers grew up, more particularly as for a while it was the sensible course of Nature which absorbed their attention: and this outline, in the extreme dearth of direct statements on the subject, can only be made even tolerably complete by comparing such details as we have with the fuller record of undeveloped states of practical belief elsewhere in which the same features recur. The cosmological myth of Kronos, for example, the significance and world-wide distribution of which has been studied in detail by Andrew Lang in his *Custom and Myth,* is a typical aspect of the view of the world in general which was current in the Aegean in the generation of Thales; diagrammatically and figuratively expressed, indeed, in such parables as this, but none the less approved by general consent as a working hypothesis, and found tolerably consistent in practice ; exceptions 'proving the rule', in the strictest sense, when examined *secundum artem.*

It would be easy to multiply examples of the way in which this unpromising substratum of popular, pre-

scientific conceptions coloured, distorted, and in some cases even directly originated the conceptions of Greek rationalistic philosophy. Greek hylozoism in the sixth century is immediately descended, and but a step removed, from the undisguised animism of the eighth; the doctrine of Metempsychosis is hardly explicable at all, except as an inference from totemistic beliefs, which need no more than mention; and the side of Pythagorean doctrine which is least obscurely presented, looks like nothing so much as a belated and archaistic revival of obsolescent *tabu*—practices which, however, are found in full ritual observation, if with dimmed appreciation of their meaning, at a very much later date, and are even yet not wholly extinct. Pythagoras himself, like Epimenides in the preceding century, and Empedocles in the next, and countless ephemeral ἀ,ύρται besides, appears to have found no difficulty in combining the profession of philosophy with the practice of common magic.

From this point of view, indeed, the ethnography of logical and metaphysical theory may come to occupy no mean place among the Human Sciences; certainly it already offers material for obstructing more than one blind alley of anthropological and even of philosophical research. And when it is remembered that the reasoning apparatus of the individual of to-day passes in its development, like so much else of his more physical equipment, very closely along the lines of growth of the rational faculty of the species; that the chances are that every philosopher or experimenter among us has passed—unless he was a very abnormal infant—through a recognizable stage of almost unqualified animism, usually with concomitant manifestations of magical and fetishistic practice; and that with many people such beliefs and practices persist uneradicated into maturity; it will, I think, be clear that the examination of certain principles

of primitive thinking may be not entirely without value in regions nearer at hand. Let me illustrate such primitive thinking by a diagram; not an actual instance, but a narrative summary of the gist of many such.

A savage, resting in his cave on a windy night, hears howling outside. Nothing is to be seen to account for the noise, but it—whatever *it* is—howls like a wolf: or rather (he thinks) it is not an ordinary wolf; but if a wolf were big and fierce enough, it would howl like that. So far we have a hypothesis, just as rational and adequate in itself as when a physicist like Lord Kelvin thought that certain electrical and optical phenomena reminded him of the behaviour of the smoke-rings people make when they sit and smoke: not of course ordinary smoke-rings, though they have little enough in them; but *if* a 'vortex-ring' were small enough, and rapid enough, which implies movement in so rare and elastic a medium that there is *nothing* there at all, it would roll and travel like that. So far, between myth and scientific hypothesis there is no difference at all, except that Lord Kelvin's myth of a vortical universe is wilder far than the savage's hypothesis of a wind wolf.

Now the savage did not know what really made the howling, any more than Lord Kelvin knew what light or electricity really is; but he knew what a wolf was, as Lord Kelvin's pupils knew about smoke-rings; and with that to go by, wrong as it was, the savage felt rather less 'in the dark' about the noise, for he had brought it into relation with the rest of his own experience. In the same way, I imagine, a student of elementary chemistry feels rather less in the dark about oxygen and sulphur (of which we really know very little as yet) if instead of 'oxygen' and 'sulphur' he writes down the numerals 16 and 32. The wind-wolf in fact is the savage's notation for the cause of that noise, as I might write 'violet' as

a notation for the rays at one end of the spectrum, without any pretence that the violet in the light was the same as the violet in the shade. Language is full of such myths, the detritus of a mountain of hypotheses: *sun-rise, full moon, influenza, good humour* are such outworn 'parables of Nature'; just as when a Nile-side Egyptian depicted the 'Boat of the Sun', or a 'horse-taming' Greek spoke of his 'chariot', or a Jewish philosopher, with one eye on his athletic neighbours the 'lords of the Philistines', described him 'coming out of his chamber, and rejoicing as a giant to run his course'; or as a San Francisco cartoonist, after a spell of rain in 1914, drew a jovial personage traversing the sky on an aeroplane.

It is in a third and quite subsequent stage that the comparison between myth and scientific hypothesis ceases to hold good. Not that the savage does not apply his discovery, such as it is, to elucidate other noises; but that he does not, before doing so, make adequately sure of its implications; in other words, he omits to verify his hypothesis. This may be a sin of omission, when panic sets the pace and he thinks he knows *enough* about it to save his skin; but it may also be a sin of commission, in so far as he thinks he knows *all* about it, when he does not; and that is the sin not of Fear, but of Pride.

Thus the reasons for the failure to push beyond hypothesis to explanation—or as a Greek would say, to pass from μῦθος to λόγος—are in the main the same two causes of intellectual paralysis, of 'losing one's head', with which we began, namely Fear and Pride. Our savage knows quite enough about wolves to avoid going out at night while howling goes on. With such a howling, common prudence argues irresistibly against experimental verification: and it is at this point, of omission to test and (in the older sense) 'prove' the hypothesis, that mythology has its frontier with science: a myth being

unverified hypothesis of what is really happening, as well as symbolic notation for what appears to happen, such as poets and men of science alike employ. And the paralysis, wrought in this instance by fear, may be wrought no less by pride, in the not unlikely event of the wind-wolf notion working in the mind of its originator, in mere consolation of his fear, or in emotional enhancement of his apprehension of the noise as wolf-noise, so that conviction seizes him, or perhaps seizes first his fellows in the cave, and the mere achievement of such a guess, like any other creative activity, satisfies his sense of need, as food, or song, or graceful movement expel desire and establish a sense of well-being from which modern speculators are, I believe, not wholly exempt. It was a sound psychologist who portrayed the Creator looking upon the work that he had made, 'and behold it was very good'.

The Law of the Jungle then is Panic, and the Avoidance of it. Provision for to-day—not to speak of the morrow—is effected just so far as the savage equivalent of what we call 'shell-shock' permits, man differing above all from other animals in this, that he alone is consciously at war with Nature; winning occasional victories and surviving to enjoy such truce as they bring; occupying now and then some patch of lotus-land, till, honeysweet as the first, the last fruit falls from the tree and dearth begins again; but conscious of defeat, no less than of achievement; conscious most of all that, whatever may happen to himself, Nature never tires, and has ever new reserves of unconceived surprise. Only because, while Nature *does* not tire, Man *will* not, does the divergence between man and animal grow, and not vanish again; at all events for those stocks, few at best, and perhaps one only, which in fact remained human, and became *us*.

In all this welter of occurrences, only two maxims (if

we may call them so) proved their validity in practice. Out of all the proverb-lore of early Greece—where I think we find most coherently the conclusion of the whole matter as less clear-thinking folk experienced it, while they failed to formulate—these two only were inscribed in the Delphic Temple:—γνῶθι σεαυτόν and μηδὲν ἄγαν: *know thyself: thus far and no farther.*

The first, as we shall see, works positively and profoundly throughout this elementary stage. Among all changes and chances in the world of his experience, it is only in respect to one class of changes that a man can pass behind the veil of appearances; namely in respect to what, as he says, *he does himself.* Not unnaturally, he interprets other changes that go on around him, other relations of cause and effect, in the light of this unique class of experiences. On this analogy between *act* as he knows it, and *fact* as he perceives it, rests all animistic explanation, from the *wakónda* of Omaha philosophy, and the ἀρχαί (which we feebly translate as 'causes') of pre-Socratic Greece, up to modern vitalism and Christian theology. This analogy he applies least unsuccessfully, where modern psychologists feel it to hold most truly, to explain the *facts* of society as *acts* of persons like himself. Conscious of that in himself which makes for action, he imputes to his fellows, in greater or less degree, what we might crudely describe as *me*-ness, the Polynesian *mana*, the Omaha *wazhín.* The nearest Greek and Roman equivalents for it, in its moral and personal aspect, are respectively *virtus* and ἀρετή; on the social and political side *imperium* and ἀρχή, the last-named being (as will be seen) identical with the term applied to impersonal 'initiatives' in the world of non-human fact.

Yet another aspect of this analogy is the Greek use of αἴτιος to denote the person responsible for a moral or

social act, and of αἰτία for the necessary antecedent of any occurrence, the 'cause' of any 'effect'. Just so in Latin the corresponding word *causa* itself comes into metaphysic from the law courts,[1] so that the Latin legal term for human responsibility, which Cicero thus defines [2] *ea est quae id efficit cuius est causa, ut vulnus mortis*, becomes a medical term for any disease, i.e. anything responsible for deficiency of me-ness in me: [3] so that the modern French *chose*, and the Italian *cosa*, is the colloquial word for any mere *thing* or external object; and even among ourselves a *charwoman*, I hope, retains her proper meaning, as a person *who gets things done*.

Now 'me-ness' of this kind, the driving personality of the agent, exists, as the more social animals already show, in very different degrees in different individuals. It also exists in the same individual in varying degrees on different occasions. Most of us probably have been occasionally in the predicament that 'virtue is gone out of' us. It may be diminished by want, or exposure, or fatigue; still more perceptibly and rapidly by blood-letting, shock, or poison; more obscurely too, by disease and less-obvious 'causes'; by hate, love, despair, or the weather. It may on the other hand be enhanced, by drugs, emotions, or ideas, that make us, as Americans say, 'feel good'.

To judge from recorded practices, in almost all simple types of human communities our natural expectation is more than realized, that personality, so conceived, has been the subject of peculiarly intense thinking and elaborate precaution. The interpretation and enhancement of the personality of the Performer; the removal

[1] *Causam dicere* (*agere*) = to find out who is responsible for what has happened.

[2] Cic. *de Fato*, 15. 34.

[3] *Causam metuere*. Celsus, 3. 3; cf. *causaria missio* = sick leave.

of obstructions of every kind to achievement; in particular the concentration of facilities at the disposal of individuals of outstanding personality; and the enhancement of personality in those at whose disposal such facilities are, are obvious motives for a very large part of the mental efforts of man in simple societies, and for many of his performances outside the mere round of daily needs.[1]

The other maxim of Delphi is not quite so easy to illustrate as a principle of primitive thought. In popular Greek morality, it expressed in practical advice the belief in a world-order within which man moves and acts. This idea of a world-order hardly reaches the degree of humanized personification which we look for in Greek religious myth, and we have seen that its opposite, too, the freakish misrule of chance and surprise, was only partially humanized in the goat-footed, goat-minded Pan; but there is fortunately preserved in a provincial sanctuary at Rhamnus in Attica, a presentation of *Nemesis* as a goddess of wild things and wild places, with wild apples in her hand, and little stags leaping wildly among her hair. It is she who, representing what we call the 'order of nature' or more precisely, the idea of order *in* nature, presides over the wild places and their denizens, 'giving them their meat in due season' like the Providence delineated in the Hundred-and-fourth Psalm. Like that Providence too, this physical Nemesis is the physical counterpart of that social Nemesis which has become traditional in Greek and subsequent speech. Nemesis

[1] I need only refer in illustration to Mr. E. S. Hartland's address to the anthropological section of the British Association at York (*Proc. Brit. Ass. Adv. Sci.*, York, 1906), to Miss Alice C. Fletcher's monographs on *The Omaha Tribe* (Mem. Bur. Am. Ethnology, 1911) and *The Hako, a Pawnee Ceremony* (ibid. 1905); and to Dr. B. Malinowski's *Argonauts of the Western Pacific*, London, 1922.

indeed, as Miss Harrison and Mr. Cornford [1] have shown, is little more, nor less, than the world-order, within which man moves and struggles at his peril. And his dilemma is this: if his 'me-ness', his personal ἀρετή, the 'drive' or 'virtue' which keeps him going, be not adequate to his needs, there is no evil chance to which he may not fall a prey. Yet if his achievement pass beyond a certain margin of adjustment, between himself and the wild which is about him, no less than between himself and his human neighbours (who are not wholly of himself, any more than they are wholly alien and part of the wild), there is risk of mishap from non-human forces, just as there is risk from offended or injured neighbours. It is essentially a risk unknown and beyond his present power to estimate: an essential quality of the wild, which is for him at least 'without form and void': ἄπειρον, limitless. And the sole remedy and precaution available to man is once again not merely to know *what he can do*, but to know *what he is doing*. To know *what he is doing*, indeed, is a first step to an estimate, first, of what is yet undone; and then, of his power either to do the rest, or not. Side by side with Pan and the ἄπειρον stand πέρας and Nemesis; side by side with *mana*, with *wazhin*, with ἀρετή, with ἀρχή, stand *tabu*, avoidance, μέτρον and τέλος.

It would be instructive, and easy (did space permit), to illustrate, side by side with the salutary working of such 'self-restraint', the disastrous consequences when Pride, in the person of the seer who believes that he knows, in virtue of his double portion of discernment, reinforces prestige by unholy alliance with panic Fear; *tabu* sustaining *mana* and perverting aristocracy, which is the rule of the seer, into oligarchy, the despotism of an 'inner ring', with its watchwords '*hush-hush*'

[1] Miss Jane E. Harrison, *Themis*, Cambridge, 1910; F. M. Cornford, *From Religion to Philosophy*, Cambridge, 1910.

and '*verboten*'. Nobody likes amateur intervention in matters of which he at least knows the perilous delicacy; and it is only too easy for the niceties of magical manipulation—so liable in any case to miscarriage, seeing how unproven hypothesis is sport for Pan and tragedy for Nemesis—to be restricted to the gifted or cunning few. Not that specialism is not liable to occur in far later stages of rational scientific research, with the same ominous consequence of the formation of an 'inner ring'. For the seer, ancient or modern, remains human, after all; and the key of knowledge has been used at times to double-lock the door: 'this people that knoweth not the law are cursed'.

To illustrate the baneful effects of Fear, I have dealt separately and in the first place with what I have described as the 'panic' aspect of man's attempts to deal with external nature. It predominates wherever the balance of forces sets so heavily in favour of nature, and against man, that man's strategy in the conflict is defensive mainly; and in life, as in warfare, 'a purely defensive strategy means ruin'. Terrible as is inhuman nature, in this kind of struggle, a person armed with however little of nature's weapons, as the witch doctor claims, and may well believe that he is, is more disastrous still. Panic fear is bad enough, for it makes men 'lose their heads'; when a human personality rides the storm and directs the thunderbolt, a man may 'lose heart' as well. Within the mere slums of the rain-forest, there are criminal quarters, here and there, and cruel habitations.

Yet it is in some such surroundings as these and in monsters like the king of Benin, with whom we began, and other panic-mongering potentates throughout West Africa, that we trace some of the first extensive, if momentary, successes of the 'drastic man', armed with his own knowledge of himself, and intelligent enough to make the

relative helplessness of the others the pretext and justification for helping them, provided he may do it on his own terms.

§ 2. *Pride: Priest-kings and the Laws of the Gods: 'Magic' in the Ancient East*

We have taken as extreme instances of the Jungle Law of Panic those regions of the earth where nature most completely overwhelms human initiative and defaces the rational aspect of human endeavour.

In contrast, we may look to those rare regions where the balance sets so far in favour of Man as to allow not merely those adaptations of animals and plants to his uses which are common to tribally organized societies throughout the north temperate zone and far into the less amenable districts on either margin of it, but even what we may describe as the first great domestication of inanimate nature, the redistribution of water over the land surface in accordance with man's will, to make plants grow and animals breed in a land which is his by right of creation. Such domestication of water is the fundamental achievement on which are based the great river-valley cultures and the vast aggregations of humanity which these quite artificial conditions rendered possible. And here again we are confronted with the same paradox as in our first phase. On the one hand, there is here amazing industry, wonderful craftsmanship, acute observation applied to the enhancement of life in many ways; a high degree of organized co-operation on an unprecedented scale; and, perhaps most remarkable of all, a stability if not of the political superstructure, at all events of the social framework, which was only upset in Babylonia by an external shock—the Mongol invasion—so violent as to disrupt, not so much the

economic organism, as the geographical redistribution which permitted it at all. 'As it was in the days of Noe', so it was in those of the last Caliph of Bagdad; 'they ate, they drank, they married and were given in marriage, until the flood came', and Mesopotamian irrigation almost ceased to be.[1]

Yet, great as were the achievements of each of the great river-cultures, one limitation is common to them all. Once the full measure of regional adaptation was reached—and this seems to have happened rather rapidly—the main structure of society and the main fashions in all activities of life appear almost as quickly, grow soon to essential maturity, and then nothing more but such superficial ups and downs as are attributable to political conquest and temporary decline or renascence of an economic oligarchy.

There is certainly a reason for this, and in Egypt and Babylonia at all events, the facts are sufficiently well known to justify conjecture. In both regions, initial advancement follows the intrusion, among an old-established and comparatively sparse population, of a fresh element alien in culture and antecedents, but not so alien as to discard entirely either their own organization or their more fundamental ideas. It is to these exploiters, or rather to their great chieftains, that the large-scale reclamation of the region was due. Local experience and effort were organized and directed by brains sufficiently clear and competent to grasp so vast a problem and enforce a solution. The risks, as far as we can estimate them, were enormous; the returns commensurate, in the event of success; and the maintenance of an artificial

[1] Yet 'the bow shall be in the cloud . . . that I may remember the everlasting covenant between God and every living creature': and our 'victory ribbon' reminds us that the decision is ours, to accept or to reject its omen.

state, society, and economic régime depended, like the initiation of them, on perennial co-operation within rigidly determined lines.

Once again, side by side with economic and social arrangements so definite and peculiar; with the administrative genius of the men in authority, the horse-sense of their officials, and the technical skill and application of the mass of the population, applied from day to day to practical secular problems, in mere self-expression, or under the taskmaster's whip, we can recover outlines, at least, of a system of ideas which stand to the secular culture of these regions in much the same relation as the hypotheses of the Panic stage to the life of the jungle-folk.

In the first place, so elaborate and extensive an organization as a riparian state required and achieved accurate means to communicate instructions and register events: it is the same *need to do* and *need to know* as we have seen already giving rise on a lower social plane to myth and magic. Longer foresight demands accurate measurement of time and a calendar-scheme for record and for programme. Wider conceptions of area and cubic content, whether for earthen-dams, or water-flow, or estimation of produce and tribute, lead to systems of measurement, and eventually even of weight and value. To this extent the mere needs of administration enforced and stimulated new notions of quantitative accuracy, of permanent and world-wide significance.[1] No less important is the reaction of the political and economic régime on the cosmology, and the connexions between 'physics and politics' deserve closer examination.

[1] For these primary inventions of oriental science, see F. S. Marvin, *The Living Past*, ch. ii, London, 1913; and for details A. Erman, *Life of Ancient Egypt* (E. T. 1895), A. Wiedemann, *Das alte Aegypten*, p. 400 ff., Heidelberg, 1920, and B. Meissner, *Babylonien und Assyrien*, p. 355 ff., Heidelberg, 1920.

The peculiarities of the Egyptian interpretation of nature may be illustrated by analysis of some of its leading ideas. In the Nile valley, man's struggle against the wild succeeds on two conditions, of industry and observation. Physical contrasts of seasonal and regional fertility are abrupt; solar heat contends with Nile water, sea breeze with scorching 'hamseen'. Man must discern which of the Powers are his friends, and serve them; and in such a world-war, even the Greater Powers recognize service rendered. First of all Powers, as already hinted, are Sun and River; then the Bull, Cow, and Ram which his leaders brought with them, or reclaimed from the wild. These are beneficent, but require observation and maintenance, so near the margin of pasturage. Others are maleficent, and need observation too; the crocodile, scorpion, uraeus-snake. Others challenge wonder, by incessant or periodic or exceptional activity; the hawk flying in the eye of the sun, the dung beetle rolling his pellet—whither? and why?—the jackal, guarding (or is he molesting?) the dead; the ibis, ubiquitous and all-seeing; the cat, 'for all places are alike to him'; lion, hippopotamus, and many more; all elements of a ramshackle universe, precariously held together, like the baronies of Delta and Valley by the wearer of the double crown, who is 'child of the Sun', and co-regent over men with him, as his own son is his co-regent.

Large matters are 'explained' by the simplest of diagrams; creation, in a world of Nile-mud, is potter's business at bottom; the sun's daily course is a boat-journey through sky, blue as the river's reflection of it. Complex activities are surely the work of composite deities. If the same functions are performed in Crocodilopolis by King Crocodile and in Bubastis by Our Lady Puss, reason points to that which in cat and

crocodile is one, as the generic cause. And all these powers, working as reasonably as they do, are in some sense human; it is not mere ibis or lion, but an intelligent and intelligible energy like man's; and the animal head surmounts a body of which the working mechanism is human. Above all, and gradually subsuming and harmonizing this polytheism, two master-conceptions dominate and at times compete: a naturalist hypothesis, attributing all ultimately to solar-energy; and a humanist hypothesis, that all growth and maintenance is ultimately congruous with the birth and life and death of man, the only sequence in all nature, as we have seen in the most primitive phase, of which man directly knows the inwardness. And so Egyptian knowledge culminates in the facts of motherhood and childhood—Isis and Osiris—ever bearing, ever-born, and ever born again, as day succeeds night, and awakening sleep, and life death, when that which is not-us wins periodic victory over laborious beneficent manhood. With this Osiris-mystery, as with Egyptian civilization itself, we pass beyond indigenous Nile-dom, for Osiris is shepherd-king; in another of his aspects he is lord of some un-Egyptian tree, which is his written symbol; in another, his energy is vegetative rather than animal, and in an essentially agricultural régime analogies between the fate of seed-corn and that of man himself, desiccated and buried away 'till Osiris shall come', acquired profound significance, and suggested infinite precaution to conserve that unpromising remnant of *my* career, in mummy-shroud and sarcophagus, pyramid-tomb and chantry priest, against that far renaissance.

Thus Egyptian attempts to rationalize the Nile-world led first to ill-harmonized analyses of nature-forces; then to loose synthesis round twin hypotheses of solar and vital energy—Ra and Osiris—nowhere carried really

farther than political theory was carried by the ramshackle Egyptian administration and social structure; and then the lurking remnant of primaeval fear—fear of my own dissolution in spite of all—imposed the dead hand of vast insurance-societies, the great priestly guilds, on further progress in administration, in society, in economics and industry. For with a cosmology so complicated and so incomplete, only an expert could understand the symbolism, much less perform the ritual. As elsewhere, too, repeated failures of the experts themselves led to the conviction that human insufficiency through latent defect in the client—not of course in the procedure or its theory! —must be almost irremediable: so that both ingenuity and wealth were diverted from more accurate interrogation of nature into refinements of current ceremonies. Thus the 'wisdom of the Egyptians' forwent enhancement of this life, and spent itself to ensure a sequel. It is perhaps not without significance that those later systems of knowledge which have been imbued most deeply with that wisdom have been most liable to the grip of the same 'dead hand'. Lucretius feared this when Isis had but newly come to Rome: Piers Plowman heralds more effective 'protest' against it.

In its outlook on nature the other great river-culture of the Ancient East presents curious similarities with that of Egypt, and also instructive contrasts. In an artificial country like Babylonia, terrestrial nature is poor: 'in the beginning no reed was; no tree; no dry land for cities': only mudflats like those which infest the Euphrates delta to-day. Only the sky-phenomena are copious in quantity (the sky being usually clear), though simple in kind, being essentially movements of points. Once correlated empirically (which was fairly easy) with the cycle, less accurately graded, of water-flow and weather and especially of the seasonal winds, the movements of the stars were

seen to be primary, and all else coherent with them. The 'great powers', Sun, Moon, Planets, and Stars, have however a less and less orderly escort (like the courtiers and camp-followers of a king) of Winds and Storms 'fulfilling his word', Waters and Sandbanks, the latter rebellious, incalculable, 'disastrous' in the literal sense that there was no *star* that really looked after them. Then there are domestic animals, with biddable natures like those of men, and plants whose innate observance of the kindly seasons brought them under the sweet influence of the Pleiades or whatever constellation brought up 'herb for the use of men' upon the earth; and there were wild unbiddable blights and vermin, serpents, scorpions, and poison-spiders most pernicious of all. These too, like the hangers-on of temporal majesty, were to be observed, selfishly, with precaution; and bound over to keep the peace, by a 'word of might' from one of the greater gods. Now a 'great god', like a great priest-king in a temple-city, was a public benefactor, an earthly providence. At his will he could interrupt the order of your days, cut off your water, commandeer your seed-corn; or turn again and bless you with freehold land, and a place at his table. But if he was an earthly providence, he was before all things a capitalist: the earth was his, for he made it,[1] out of mud and primaeval slime; the water was his, to irrigate the just and the unjust; wealth was his to give or to withhold. But all things had their price in Babylonia; the talent, lent out of the temple treasury, to be returned at the day of reckoning with interest as per agreement, was counterpart and symbol of other 'talents' of character and skill, to be employed as under

[1] This aspect of oriental theology has gained a new vogue in our own capitalist society, as Dean Inge has noted in a sermon at Hull, 10 September 1922, during the meeting of the British Association for the Advancement of Science.

the master's eye. It was a common proverb in Babylonia, 'five years of harvest, and yet the craftsman has bread'; all skilled workmen being attached as a matter of course to some temple corporation, and drawing on its reserves during bad times. And the god could borrow as well as lend; like a Stuart monarch, he levied 'benevolences', 'free-will offerings' of his dependants; but the shareholder in a good temple, like an investor in government securities, was at all events sure of his income: and if all went well, the bonus would be ample.

> Whatever, Lord, we lend to thee
> Repaid a thousand-fold will be;
> Then gladly will we give to thee
> Who givest all.

The great nature-powers in Babylonia are, moreover, very curiously doubled with national or tribal or civic deities; and provided with consorts like a human monarch. More notable, especially in view of the light thrown upon it by what we have already seen at an earlier stage, is the worship of human beings: of the deceased king; of the living king, as chief local repository of mere power; of other important personages; and lastly and more oddly, of oneself, far in excess of any scheme of votive substitution. All these are special cases of that enhancement of a valued personality which we have already noticed, and which comes out again so oddly, farther west, in the story of Kylon the Athenian, who 'grew his hair long for a tyranny', and perished accordingly.

On the other hand, with characteristic attention to business in hand, Babylonian imagination stopped short at the grave: in striking contrast with the copious and varied speculation about the soul's after-life in Egypt. 'The tree' (in the Book of Job, one of our fullest repertories of Babylonian world-knowledge, however resolutely its author is striving to transcend it) 'hath hope; if it be

cut down it will sprout again; but man lieth down and riseth not; till the heavens be no more, they shall not awake, nor be raised out of their sleep.' Somewhere under the earth is the land without return, to which the dead pass when they 'go hence and be no more seen'. Traces of an earlier theory survive here, as in other departments of Babylonian culture, in the belief that *if* you could get at the spirits of the dead, they could tell you something. The 'land without return' was also the 'place of inquiry'; by the rather crude method of hammering offerings into the ground, you might 'get through' to the departed, and learn of them. But this needed a priest, and the fees were heavy; so heavy that in the common interest the priest-king had to intervene from time to time with a tariff of charges, as a modern township fixes cab-fares. For what the god-king did in his temple, and the priest-king in his court, the general practitioner of the same 'applied science' did among his private clients; a capitalist economy carried all things human and divine to a profit-and-loss account. 'Justice is mine, I will repay' was the common law of physics, politics, and theology.

Thus in Babylonia, and rather less clearly and crudely in Egypt, much that at an earlier phase was paraphrased by myth is now found amenable to explanation, capable of being verified by recurring experience; and this is mainly due to the circumstance that in organized society, with adequate means of *record*, observers multiply in each generation, and observations can accumulate in time. Natural history at all events is found to repeat itself; a general order, intelligible to man, is made out, and attributed to the foresight and administration of the Great Powers. Thence emerges a hypothesis of Providence, and a formulation of the Will of the Gods, which for man are laws, like the laws of Hammurabi: we have echoes of such an astronomical Digest in the Hundred-and-

fourth Psalm, 'He hath appointed the moon for certain seasons, and the sun knoweth his going down'; more distant echo still in the fragment of Heraclitus, 'the sun will not overstep his landmarks; if he do so, avenging spirits, minions of the law shall find him out'. But the 'Code' is not absolute, nor complete; the gods of a Theocracy do not yet find all their work 'very good'; any more than Khammurabi or Ur-kagina may rest from their labours. The 'great dragon underground', or rather in the lower fens, is not yet dead: his head is bruised but not broken by the 'seed of the woman'. Only by divine foresight—let us call it by its Roman name of 'Providence' while noting that it is neither all-seeing, nor all-powerful yet—can man preserve from bruises his own Achilles' heel. Providence, that is, is reinforced with Miracle; for as long as miracle is possible, Equity supplements the Code; Justice is tempered with Mercy. And as long as Mercy, Equity, Miracle, remain, Magic remains too; the possibility, namely, of somehow getting the judge on to the right side, or yourself on to the blind side of him. Thus with an organized religion, we find magic organized too, and the name *mage* and *magic*, like the Roman equivalent *Chaldaean* and our own *Gipsy* (that is, *Egyptian*), mark the modes in which this organized Magic penetrated into the West.

§ 3. *Honesty: the Citizen and the Law of Nature: 'Physic' in Mediterranean Lands*

It is a relief to turn to that other region whose early effort and thought are so large a part of our own. Greek Science, in its eventual maturity, falls to others to illustrate. But here too there has been a long pre-history; for the Hellenic civilization of the last six hundred years before our own era has been shown within the last

generation to be the sequel, and in some degree the heir, of a prior culture, in the 'Minoan' Bronze Age of Crete and the Aegean archipelago; and though the higher aspects of the pre-Hellenic culture remain unrevealed, so long as its script is undeciphered and its language unidentified, the mode of life which this region imposes on its inhabitants in all ages is sufficiently recoverable for an attempt to be made to sketch at all events that background of popular beliefs among which the first Greek thinkers were brought up, and the beliefs about 'that which surrounds us' with which their interpretation of nature started.

First, Herodotus's brief eulogy of the climate and circumstances of Ionia reveals an 'earthly paradise' which nearly three thousand years of human depredation have not wholly disfigured. 'These Ionians happen to have founded their communities in the fairest climate and seasons, of all people within our ken. Neither the landward regions to the east nor the seaward to the west render aught like unto Ionia; oppressed here by cold and wet, there by heat and drought.' Under that clear sky and limpid atmosphere, seldom too hot for man's rational effort or too cold for a genial response from nature; among those rigid landforms, whose every profile confesses the ceaseless sculpture of sheer rock by mere weather, no less than the perennial increment of fertile silt therefrom, to the service of man; with intermittent heavings and lapses of island and continent, to demonstrate how sea and land have come to be so subtly interpenetrated; and with an annual cycle of plant-life illustrating, more eloquently than any other, how life and death, and again new life and death, stand related to a cosmic order of larger scope and infinite but not unknowable interaction between its component 'elements'—earth, water, air, and that ethereal 'fire' which we call

solar energy—what wonder if in seasonal and diurnal intervals of enforced leisure from the task of exploitation, Ionian Greeks looked about them with clearer vision, wholesome release from the shell-shock of catastrophic environment, ampler anticipation of a commensurate issue from honest observation and fearless experiment with 'the way things grow'? [1] In that Aegean 'paradise', the tree of knowledge grew in every man's garden, and the fruit of it was his, in its season; for his fathers had planted it there, and he himself had dug about it and enriched the roots of it.

We have also to take account of two facts on the human side of the reckoning. First, neither the more pushful components of the Greek people themselves, nor those Olympian occupants of the high thrones, exuberant as their votaries, were indigenous to the Mediterranean coastlands. Zeus did not make that world, nor Poseidon the land or the sea. They had found them and occupied them; by superior humanity—clear brain directing deft hand under imperious will—they had repelled the last rebels of an 'earthborn' régime, and penned them down and under. They could make 'tenants' improvements', like the gorge of Tempe, and thwart the plans of man, their own bailiff, for a Corinthian canal or the insulation of Cnidus from Asia Minor.

'Zeus would have made it island, had he willed.' But, as Aeschylus at all events knew, Zeus had no freehold

[1] We have to remember here that the disastrous mistranslation of φύσις, 'the way things grow', by the Latin *natura*, 'the way things come into being', had not yet perverted men's thoughts from observation of processes and detection of uniformities of 'behaviour' in the present, to speculations as to the origin of it all, and inferences as to the probable character of One who could 'make all things out of nothing' by the 'word of his power', not to mention making wine out of water, or victualling a brigade with 'a few small fishes'.

in Olympus. Only by a fresh bargain with the champion of man's right to the full means of life—to celestial fire as well as to earth, water, and air—could he insure even an extension of his lease. 'While the strong man armed keepeth his palace, his goods are in peace'; but Titans or the Son of Io might threaten Olympus again, as the Persians broke ultimately into Ionia. In a physical world, only one thing is stronger than its forces, and that is humanity, rightly used.

Secondly, in this royal sport of finding out 'how things grow' and making them grow to man's convenience, only one peculiarity in the constitution of 'that which is around us', which might have been so deadly an opponent, gave the final victory to man: and that was the rule of law in 'that which surrounds us' no less than among the sons of men. 'The sun will not overstep his landmarks; if he do so, avenging spirits, minions of the law shall find him out.' This belief of Heraclitus that 'the very devil of a police' controls the traffic of the cosmos, with penalties 'to fit the crime', was an almost inevitable metaphor from the only illustration of 'law and order' which he and his contemporaries were competent to study 'from inside'. For not only had the Olympian gods, and those human votaries who introduced them, no birthright in Aegean lands; the subsequent crisis which broke down the Minoan civilization, and flung fragments of its peoples on to the lee-shore of an Asia hitherto impervious to it, appears to have shattered existing society so completely almost everywhere, and most of all among these farthest refugees, that they had literally, as in the social philosophy of Aristotle, to 'get to know' one another; for 'he who first introduced them to each other was author of the greatest blessings'. Out of these emergency camps of social, unrelated Crusoe-men, 'formed', as folk-memory taught the later thinkers, 'to

maintain life' but with conscious ulterior aim 'to live well', as men had lived in the Golden Age before the cataclysm, arose the 'city states' of historic Greece; almost the only type of human society of which it is possible really to know the origin. In these strenuous circumstances, human behaviour was just as urgent a subject for observation and experiment as the climate and soil and food-plants of the new home. The gods, it was true, had allowed a few men to survive, out of a world that, as the legend put it, was 'too full of people'; but they had not done much more; and the pathetic indulgence of the Greek towards his Olympian friends—for they were friends and associates rather than his lords or masters—when again and again they fail him in his time of need, is a notable sequel to the catastrophe with which Greek culture begins. The Greek never ceased to like his gods; there they were, old friends of the family; so he made the best of them, and treated them courteously, and as generously as he could afford. But he neither feared them nor trusted them very greatly; least of all in a pestilence or a world war, unless perchance they 'did their bit' like Apollo at Phigaleia.

Physics and politics therefore, in early Greece, were collateral branches of research; and the terminology of 'physics', when we first catch a glimpse of it, is indebted to the sister science for its more important terms, no less than for its earliest exponents.[1] 'The Seven Sages', says

[1] This is perhaps the point at which to explain why no account is taken, in this survey, of the other great interpretation of nature which we owe to Indo-European folk. On the political side Zoroastrian thought went farther, in its earliest phase, than any Greek speculation before the fourth century. But it remained anthropocentric, unaccompanied by any such interpretation of the physical environment as occurred in early Greece and never wholly lapsed; and it may be asked, whether the renunciation of physical studies by such men as Archelaus and his younger

Dicaearchus, 'were originally neither learned nor students, but men of common sense with a taste for legislation'; and of Thales we hear that 'it was after his political career that he devoted himself to speculation as to how things grow'. Similarly Anaximander, who came like Thales 'from politics to physics', is described as using 'somewhat poetical terminology' to describe physical phenomena; 'to do sentence and reparation for their wrong-doing, in the order of time' or to describe how 'into those elements, from which they have their birth, things that exist have their dissolution, according to their obligation', is certainly an odd way of describing biological cause and effect. But it is the same immemorial inference, that we have encountered already, from processes of which we feel we know the cause within ourselves, to the unknown causes of processes observed in that which is 'not us'. So Heraclitus, dark though his teaching is, in the fragmentary utterances which have been handed down, conceived 'that which surrounds us' as 'reasonable and intelligent'; he held 'wisdom to be this alone, to know the judgement which steers all things through all'; dividing his great treatise into three accounts, 'that of the whole' or 'things in general', the 'civil', and the 'theological'; and describing this threefold exposition of gods, men, and nature as an 'accurate chart for estimating human life', or more briefly and comprehensively as a 'judgement of behaviours'. His method he described concisely as 'distinguishing things according to their way of growing, and demonstrating in what state they are'.

Thus, in Greek 'city states', and between Greek sky and Greek soil, came substantial release from fear of vast

fellow student Socrates was not in part due to a century of converse between the learned of Ionia and sincere Zoroastrians among the Persian officials.

inhuman forces, once the stresses of the migration period relaxed; and release, no less wholesome, from whatever of theocratic rule had tightened the discipline of the *Minoia regna*, with its palace-dungeons, its bull-worship, its gladiatorial orgies, as we trace them on Cretan sites or in Greek folk-memory; or had gripped the survivors of that régime under the shortlived conquest-rule of Homer's 'divine-born kings'. Already in Homeric narrative the twin conceptions of *aidôs* and *nemesis* (*my* feeling that this or that is out of bounds, for *me* or for *him*, respectively; and that it is for *him and me* to seek out and put straight what goes amiss) were leading to a moral honesty which considered the observer's neighbour as he considered himself. And the counterpart of this moral honesty was a mental honesty, as we have seen, which, 'considering' the observer's self, 'considered' also 'the lilies of the field, how they grow', and under the twin conceptions of *physis* and *nomos*, 'growing' and 'mode of behaviour', embraced and interpreted the whole complex of 'that which surrounds us' as something 'rational and intelligent'.

Not all the lore which early Greece collected about 'the way things grow' or the 'modes of behaviour' of 'that which surround us' would have stood the stricter test of a maturer logic, any more than the conduct of Greek citizens or Greek states conformed to the Delphic maxims of self-knowledge and self-control. But between the magic and ritual of those earlier theocracies which preceded the reasonable freedom of the Hellenic outlook, and the relapse into pride and fear which came when the half-Hellenized East joined hands with a half-Hellenized West across the Macedonian and Roman conquest-empires, the physical and the political philosophy of the Greeks stands out distinct, coherent, and humane; as the Baconian rationalism stands, in 'physics' and in 'politics'

alike, when after long theocratic eclipse it re-translated *natura* into *physis*, and *lex* into the *nomos* of Hellenic science.

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II

ANCIENT MEDICINE

CHARLES SINGER

§ 1. *Early Greek Rationalism and its relation to Medicine*

THOSE who have to deal with the ignorant and backward—a class by no means confined to the lowest social stratum and to the least accessible countries—frequently find themselves in contact with customs and practices that are described as 'magical'. During the last generation anthropologists have given a great amount of attention to these customs, and it has become evident that they represent a survival of an earlier and pre-scientific attitude to Nature. The general character of the beliefs—if beliefs they can be called—underlying these practices and this attitude can now be reconstructed. The reconstruction is aided by the fact that the attitude which we may call 'magical' is not peculiar to one race or people, but is the common heritage of mankind. The survival of such beliefs in certain classes among highly civilized peoples is a most important and interesting psychological phenomenon, and one well worthy of more attention than it has yet received.

It has become more and more evident, as a result of recent investigation, that man is even less a creature of reason than had been thought. In many or most matters our opinions are formed first, and the logical justification of them is the result of a later mental process. This fits in well with the general conclusions of anthropology that, in an earlier stage of man's development, feelings and impressions may give rise to actions which appear quite contradictory to the rationalizing mind. Such actions

we can now see are inconsistent because they are not linked together by any clear body of belief.

When such contradictory or inconsistent actions are considered to be of a 'religious' character they have frequently been gravely misunderstood by investigators. These have often the models of the higher religions before their eyes, and have regarded ritual as something based on a definite *faith.* It is, however, only in a later stage of his development that the vague and inconsistent attitude toward the world around him becomes elevated by man into anything that can be called a consistent religion or body of belief. That stage was reached in ancient Egypt.

A yet further stage shows man giving reasons for the faith that is in him. It is evident that this stage had been nearly reached in Mesopotamia, but was more clearly attained in ancient Judaea. Religions on this higher stage seek to justify themselves and to explain their origin and nature. They develop ritual into a legal system and a fixed sacred tradition. It is a stage that clearly corresponds to the present needs of the vast majority of mankind. The great religions are largely in this stage, and all have sought to provide their followers with an explanation of the world in which they live. These cosmologies were once the very bases of the appeal that the religions made to the rationalizing mind. It is evident that on another mental level cosmologies form an obstacle where they were once an aid.

Following on what we may perhaps call the 'cosmological phase' of religion comes a further stage in the mental development of man. He finds that his world is not only subject to laws, but that those laws are further and further discoverable. By accumulating experience and by investigating these natural laws as betrayed by phenomena, he finds at last that even his own opinions

and thoughts are the subject of laws, and he seeks to know something of them too. Without this knowledge he cannot understand himself, for to do that he must first seek to learn how he came to be what he is. This last stage, which we may call the scientific stage, has proceeded but a very little way. It cannot as yet be traced back with any clearness beyond the Ionian Greeks of the sixth century B. C. It is with them that the scientific idea begins.

In order to avoid misunderstanding it is necessary to enlarge a little on this statement that the scientific idea begins with the Ionian Greeks of the sixth century B.C. It is not suggested that the careful and accurate observation of nature began with them—in such observation every hunter must be an expert, and we have evidence of its existence far back in palaeolithic times. Nor is it even suggested that the Ionian Greeks were the first to formulate general laws concerning natural phenomena. The Ahmes papyrus of about 1700 B.C., believed to be founded on much older work, shows that the Egyptians were in possession of certain mathematical laws even at that date. The Ionian Thales of Miletus (*c.* 640–*c.* 546 B. C.), the founder of Greek geometry, astronomy, and philosophy, predicted the eclipse that took place on 28th of May 585, but he did this from data derived from Mesopotamian sources. Astronomical observatories were, as we know, to be found in the great cities of the Euphrates valley at least as far back as the eighth century B.C., when professional astronomers were taking regular observations of the heavens. Similarly rational Greek medicine can be shown to have been preceded, in some of its findings, by the Ebers papyrus of about 1500 B.C. and by the Babylonian records.

It was thus not the *practice* of science which the Greeks invented but the *scientific idea*, the conception that the

world was knowable, inasmuch and in so far as it could be investigated. In ancient times this idea led to a special point of view and to some amelioration of man's lot. In modern times it has led to a complete transformation of our mode of life, to a profound modification of the inter-relations of peoples and to an alteration in our attitude to each other and to the world around us. It would be idle to pretend that these changes have been entirely to the good. We believe, however, that an impartial survey of the general effects of the scientific idea upon men's minds and hearts throughout the ages, such as this book is intended to provide, will result in an overwhelming verdict in favour of science as a very beneficent and humanizing instrument. In helping man to gain a clear idea of the knowable world, science has also helped him to understand his fellow-man.

To give any adequate account of the ancient conception of the knowable world would demand a description of the whole course of Greek philosophy. Works containing such an account are readily available. Here we are only concerned with the special application of rational ideas to the known physical universe. This is the department which we nowadays call *science*, a department which was in antiquity by no means always clearly separated from philosophy. The first writer to make clear in practice this separation between science and philosophy is said by tradition to have been the Coan physician, Hippocrates the Great. The earliest scientific works that have come down to us are medical in character and bear his name.

If then Greek philosophy sought to give a rational basis to our knowledge of the world, it was Greek medicine that first put that rational basis to the test. It is in Greek medical writings too that we meet some of the noblest and most effective expositions of that rational spirit which

separated the Greeks from all the other peoples of antiquity. There is one great monument of the rational spirit in medicine to which we must especially refer. It is the work known as the *Sacred Disease*, the condition that we nowadays call epilepsy. This wonderful book may fairly be called the 'Charter of Science'. It was prepared a little before 400 B.C., perhaps by a writer who dwelt on the Greek mainland.

The *Sacred Disease* bears now the name of Hippocrates, but it is very unlikely that it is in fact by him. In attempting to give some idea of the nature of early Greek rationalism, we cannot do better than make an abbreviated and paraphrased version of this magnificent work. In the original much space is given to a description of the physical conditions which were believed to underlie the phenomena of the disease. The explanation thus provided is quite rational and satisfactory according to the knowledge of its day. It is, however, not in accord with modern physiological teaching, and, being without value for our immediate purpose, is here omitted. It is the existence of the attempt to rationalize phenomena rather than the exact nature of that attempt that we would here stress.

'As regards the disease called *Sacred*, to me it appears to be no more divine than other diseases, but to have a natural cause from which it originates even as do other diseases. Men regard its nature as divine from ignorance and wonder, since it is a peculiar condition and not readily understood. Yet if it be reckoned divine merely because it is wonderful, then instead of one there would be many sacred diseases.

To me, then, it appears that they who refer such conditions to the gods are but as the charlatans, conjurors, and mountebanks who claim to be excessively religious and to know what is hidden from others. These men do but use divinity for a cloak to their own ignorance. They give out that the disease is sacred and adopt a mode

of treatment that shall be safe for themselves whatever happen. They apply purifications and incantations and all manner of charlatanry, but mark! they also enforce abstinence from unwholesome food. All these things they enjoin, they say, with reference to the divinity of the disease. If the patient recover, theirs is the honour; if he do not it is the god, not they, that is to blame, seeing they have administered nothing unwholesome.

But consider! Surely if these foods aggravate the disease and it be cured by abstaining from them, then the god is not the cause of the disease at all, and they who seek thus to cure it are by their very act showing that it is neither sacred nor divine. Nay, more, in the very assertion of its sacredness and divinity their discourse savours of impiety, as though there were no gods.

If these fellows professed to bring down the moon, to darken the sun, or to induce storms or fine weather, should we not accuse them of impiety, whether they claimed this power as derived from the sacred mysteries or from any other knowledge? And even if they could do these things, I, for my part, should still not believe there was anything divine therein, since the divine would have been overpowered by human knowledge and have become subject thereto.

As for this disease which they call divine, surely then it too has its nature and causes whence it originates, just like other diseases, and is curable by means comparable to their cure. It arises—just like other diseases—from things which enter and quit the body, such as cold, the sun, and the winds, things which are ever changing and are never at rest. Such things are divine or not—as you will, for the distinction matters not—and there is no need to make this division anywhere in nature, for all are alike divine or all are alike human. All have their antecedent causes which can be found by those who seek them.'

That it has set forth such doctrine as this constitutes alone an overwhelming claim of Greek medicine on the gratitude of subsequent civilization.

But Greek medicine has yet other claims on our consideration. Among departments of the scientific know-

ledge of the ancients, medicine takes a quite peculiar place in that it begins very early as an independent study, while its history, perhaps more than that of any other science, can be traced as a continuous whole. Moreover, alone among the sciences, medicine had its humane aspect and deeply influenced the lives of men. This was realized even in antiquity, and is voiced by the author of the 'Hippocratic' book of *Precepts* when he wrote—'Where the love of man is, there also is love of the Art.' In the Greek medical writings Medicine is always thus referred to as *the* Art without further qualification. And note, too, that it is a τέχνη, an *Art*, a piece of applied knowledge, not an ἐπιστήμη, a *Science*, a thing cultivated in and for itself. There never developed in Antiquity any separate disciplines of the ancillary sciences, Anatomy, Physiology, Pathology, and the rest. All were still part of the great subject of medicine and were studied only as equipment for the practice of *the Art*.

Scientific medicine thus began in Greece. The Greeks not only gave us the first start in rational medicine, but have also provided almost all our medical nomenclature and very substantial basic elements of our anatomy, physiology, pathology, and therapeutics. When to this we add that our clinical tradition is inherited through a direct and continuous chain from the Greek practitioners, and that they have set the ethical standard to which our physicians still swear fealty, it becomes evident that the debt that medicine owes to this marvellous people is great indeed.

§ 2. *The Sources of Greek Medicine*

Now this debt has become associated with a few great figures such as Hippocrates and Galen, but it is not always recognized of what a widely extended and long lasting system these men were the representatives. Greek

medical science was by no means the product of a few great intellects, but was, like our own, the result of centuries of carefully recorded, collated, and progressive experience. Greek medicine first took on a rational aspect with the Ionian and Italo-Greek philosophers at the very beginning of the sixth century B.C., and continued to make important advances until the death of Galen at the beginning of the third century of the Christian era. It thus lasted eight hundred years. With the most tolerant use of the words 'scientific' and 'progressive', can we place the beginnings of scientific and progressive medicine in modern Europe at a date earlier than the later part of the fifteenth century? Our own system has thus only been developing its characteristic features for some four and a half centuries, or but little more than half of the time that Greek rational medicine endured.

It is evident, therefore, that we may still have a great deal to learn from the Greeks, not indeed in matters of actual fact and observation—for all or nearly all that is *directly* useful in their works has been long ago absorbed into our medical literature—but in spirit and method. Above all, from a study of the character and course of Greek medical science we can gain a hint of the dangers and difficulties that may await the development of scientific thought in our own times, and the snares and pitfalls and catastrophes which may lie in the path of scientific progress.

It has been said that 'save the blind forces of Nature, nothing lives or moves to-day which is not Greek in origin'. That phrase of a great jurist needs modification; for even apart from our inheritance from other ancient civilizations, there is one thing which still lives and moves that is not Greek in origin, a blind force which is not a blind force of nature—it is the force of superstition. The Greeks were not free from it any more than we are in these days. But the greatest of them, firm in their faith in

a rational world, were utterly above such folly. We can watch the Greek mind gradually lifting itself from that primaeval mental attitude which is older than any known culture, older than any existing species of man, the attitude of magical belief, of nature-worship, of animism. To gain an understanding of how the 'sweet reasonableness' of the Greek mind gradually dissipated these age-old clouds that darkened human vision, a little must be learned about the history of the Greeks. Without that amount of history it would seem even more of a miracle than it is that man ever became rational at all.

The medicine we call Greek might really be described as the system which prevailed in ancient times in that half of the Mediterranean area which lies east of the Italian Peninsula. Up to about 1000 B.C. this area was inhabited, so far at all events as the coast lands were concerned, by that most remarkable people the Minoans. These have left some extraordinary remains, the full significance of which is not yet revealed to us, but the general development of their civilization has been laid bare by the labours of Sir Arthur Evans. The exploration of the last twenty or thirty years has resulted in an entirely new interpretation of the story which Homer tells in the 'Iliad'. The siege of Troy represents an attack by the invading Greeks on these Minoans in their last stronghold.

About 1000 B.C. the whole of the eastern Mediterranean basin was overrun by the people who became known as Greeks or Hellenes coming in from the North. Even at that date the Greeks were no longer a pure race, but a mixed group of tribes who came along at least four main lines of advance. As always happens in such invasions, the conquered were not exterminated, but mingled with the invaders, who, moving mainly southward and eastward, absorbed, no doubt, much of the culture and intellectual possessions of the civilization they submerged. Temporarily the submergence was

complete, and Minoan Art dramatically disappears. But gradually the influence of the native blood and the native point of view must have asserted itself, as it did in our own country after its invasion by the Baltic tribes whom we call the Anglo-Saxons. Many of the cults of the Greeks were surely of Minoan origin.

So far as the history of medicine goes, we are concerned chiefly with two main invading streams of Greeks: that of the Dorians who passed towards Crete and towards the Island of Cos and the opposite peninsula of Cnidus; and that of the Ionians, who colonized most of the remaining part of Western Asia Minor. These two peoples divided between them the intellectual output of the Greeks of these early days. The medical system they initiated first took shape in Western Asia Minor and thence diffused itself over the whole of the Greek world.

The Greek system of medicine which thus arose in Asia Minor had various roots, as indeed the medicine of a mixed people, living under very complex social conditions, was bound to have. Firstly, there was the culture of the conquered and submerged Minoan folk. The cult of the serpent, which is so constantly associated with the worship of Asclepios and at last became his universal attribute, was probably of Minoan origin, for the serpent was a very constant symbol of the Minoan religion. It is likely too that some of the hygienic ideas of the Greeks were derived from the same source, for the Minoans had certainly a good system of drainage. We can, however, say very little on this head because the key to the interpretation of the Minoan script is still hidden from us.

The western shores of Asia Minor lie on the outskirts of the great civilizations which had grown up in the valleys of the Tigris and the Euphrates. From that source the Greeks certainly drew much of their more superstitious beliefs, as well as much of their scientific method. Thus the demoniac theories that bulk so largely in later Greek

medicine doubtless came from Assyria and Babylonia. The medicine of the New Testament, with its casting out of devils and evil spirits, is of Mesopotamian origin. The very name of that most magical of plants, the *mandragora* or mandrake, is thought to have had a Mesopotamian source. But another and very important aspect of Greek medicine came also from Assyria and Babylonia. The Mesopotamian peoples had for long ages laid up a great treasury of observation, notably of astronomical data, but extending also into other departments. On the basis of these extensive records the Greeks were able to erect a scientific method, which appears as a prominent feature in their intellectual life in the centuries which were to follow. The Greek scientific mood has an evident relationship to Babylonian sources.

More difficult to estimate is the extent of the direct debt of Greek medicine to the Egyptian civilization. A large part of the materia medica of the Greeks was undoubtedly derived from Egypt, and so also, as some think, was the basis of Greek medical ethics. Many of the practical devices of Greek medicine, too, such as the forms of their surgical instruments, were of Egyptian origin. Nor can we afford to neglect the statement, made by the Greeks themselves, that their knowledge of mathematics, the simplest, most fundamental, and most generally useful of all scientific work, was first derived from Egypt. Considering the amount of literary material that the Valley of the Nile has yielded, the record of Egyptian medicine is remarkably deficient. The recent investigation of the Edwin Smith papyrus, of about 1700 B. C., suggests, however, that Hippocratic medicine had very definite roots in Egypt.

The advancing Greek peoples on the western shores of Asia Minor, thus deriving material from many sources, began to develop, towards the end of the seventh century B. C., a philosophical system, out of which the whole of

their science was historically a natural growth. Important factors in this development were the medical school of Cos, where Hippocrates was born, and that of the opposite peninsula Cnidus. These schools were in active operation by the sixth century B.C., and by the middle and end of the fifth they were influential factors in the growing complexity of Greek life. They soon began to react on Ionian philosophy. The actual 'Hippocratic Collection' which has survived contains some of this early material. In something like its present form it must have been first put together towards the end of the fourth century B.C., but our present recension was made in Alexandria a little after 300 B.C. It was in Alexandria that the greatest Greek medical school developed, and most Greek medical writers, after the break-up of the Empire of Alexander in 323 B.C., were trained there. It is a noteworthy fact in the history of medicine that Athens, the main centre of Greek life and thought, and the seat of the great philosophical schools of Plato and Aristotle, plays a quite minor part in the history of medicine.

Curiously enough, although we inherit the finest scientific spirit from the Greeks, and although they set us an example of the purest and most disinterested type of medical practice, they are also, in part at least, responsible for some of the basest and most superstitious forms of medical jugglery that have afflicted and still afflict mankind. The medicine of the physicians was only one of the medical systems in vogue among them. Another system of medical practice was practised by the priests, and the temple jugglery of Greece is the ancestor, both by imitation and by direct tradition, of much of the miracle-mongering of mediaeval and modern medicine. Furthermore, in ancient as in modern times, all medical men were not equally pure and scientific in their methods, and there was certainly a relation between the practice of some of the physicians and that of some of the priests.

The practice, too, of some of the priests had scientific elements in it. The relationship between these two systems is still a subject of dispute among scholars, and one which we shall not attempt to decide upon here. For our purposes it is enough to say that *in their most typical development* the two systems were distinct, and in what follows we shall treat them as such, asking our readers to bear in mind that we assume this complete separation for simplicity and brevity.

Medicine, like all other knowledge, was, as we have seen, cultivated first of all for its practical application. Alone among the sciences, medicine in antiquity never succeeded in ridding itself of the evidence of its immediate practical application. Whether or no the insistence on the *purpose* of knowledge makes for the value or even the effectiveness of the knowledge, we need not, for the moment, discuss. Certain it is that the art of medicine makes its first appearance on a cultural plane in which knowledge for its own sake is unthinkable.

Following the usual law of dissolution, that the first gained is the last lost, we shall find that the last stage to which a degraded civilization will reduce knowledge is again its practical application. There is no cultural state in which man has not a pressing need for the aid of the medicine-man. There can be found no savage race, however backward, no deteriorated civilization, however degraded, that has no medical tradition. Such tradition, however, is a very different thing from the scientific attitude which we nowadays associate with the word 'medicine'. The scientific attitude first appears among the Greeks, though that people exhibited, it must be admitted, in all stages of its history, no lack of the lower element out of which the higher had developed, and into which much of it was destined to pass again. Ashes to ashes and dust to dust is as much the law of cultures as of the beings that create them.

§ 3. *The Practice of Greek Medicine*

The temple system of Greek medicine was associated from an early date with a number of deities of whom one, Asclepios, stands out before all others. There is good evidence that Asclepios was an actual medicine-man who lived in Thessaly about 1100 B.C. and was subsequently deified. Numerous representations of this divine Asclepios have come down to us, and we see him gradually moulded to a particular type, one of the best representations of which is the fine head in the British Museum. He is usually represented as an aged man of very noble and somewhat dreamy aspect, holding in his hand a staff around which a serpent is twining. The cult of Asclepios was carried on at a large number of centres distributed over a wide area of the Eastern Mediterranean; of these the best known, both from literature and excavation, is that at Epidaurus. Other important Asclepian temples were at Tricca, Cos, Athens, and Rome.

Epidaurus is in the Argolic peninsula and about thirty miles south-west of Athens. It lies in a valley between two considerable ranges of hills, and the country bears still, in its customs and place-names, some remnants of the ancient cult. There are various traditions of Asclepios, or, to give him the more usual Latin form of his name, Aesculapius. One tradition that connects Aesculapius with Epidaurus is derived from Pausanias, an old gossip of the second century of the Christian era, who wrote a guide-book to Greece. Pausanias tells that a certain maiden, Koronis, became with child by Apollo, and brought forth on the mountain Titthion. The event is still recorded in the name Koroni, a village in the valley hard by. She fled to conceal her shame, leaving the child on the mountain, where it was tended by a goat, and watched over by a dog which was looking after the flock. Goat and dog being missed by the shepherd, he

set out to seek them, and found them with the child. He endeavoured to attract the animals from the infant, and the child thereupon sent forth flames from his mouth and eyes, and very soon, Pausanias says, this child, Aesculapius, was performing many other miracles all over the valley. In commemoration of these events, we read, the temple at Epidaurus was built.

The story is further elaborated by Pausanias in another passage of very great interest. He relates that there was still in his day at Epidaurus 'an old slab which tells that Hippolytus dedicated twenty horses to the god. The men of Aricia in Italy tell a tale that agrees with this. They say that Hippolytus, having been killed by the curses of his father Theseus, was raised by Aesculapius from the dead. On coming to life again, Hippolytus refused to forgive his father and went to Aricia. There he became a king and devoted a precinct to Artemis, where, down to my time, the prize for the victor in single combat was the priesthood of the goddess. The contest was not open to freemen, but only to runaway slaves.'

The runaway slave seeking sanctuary with Artemis in her grove, allowed his liberty and raised to the priesthood, but retaining that office only so long as he can guard it in mortal combat with the next runaway slave—this succession of priestly murders is a picture that has touched the imagination of artists and poets. The sacred grove of Artemis stood by the side of the lake Nemi:

> The still glassy lake that sleeps
> Beneath Aricia's trees—
> Those trees in whose dim shadow
> The ghastly priest doth reign,
> The priest who slew the slayer
> And shall himself be slain.

It is a picture utterly out of accord with the main trend of classical mythology. Many years ago it drew the attention of Sir James Frazer. He perceived in it the

remains of a submerged faith, the ancient nature-worship which survived among the Greeks and survives still with us. With this incident as his text he wrote his immortal *Golden Bough*. By this story and by all that it implies, by all that learning has drawn out of it and read into it, by all the haunting beauty and mystery with which it is linked, the history of medicine comes into contact with the study of the lower culture. But that is a realm that we must not enter farther. It was a more developed and elaborated worship that Pausanias had before him. In his time a great temple to a great deity had arisen at Epidaurus. The site has been excavated in our own days.

Epidaurus was but one of a whole series of temples to Aesculapius that arose in different parts of the ancient world. We know a great deal of that worship and of its associations. The treatment accorded to the sufferers who presented themselves in these temples was based on the suggestions yielded by dreams. The central element in the ritual was the 'temple sleep', the ἐγκοίμησις or *incubatio*. Everything was done to suggest to the patient that the god would come to him and succour him during his night spent in the temple precinct. These ideas gave colour to his dreams and often determined the character of the treatment imposed upon him.

Dreams! The word expresses something deeper than a mere ritual incident. The dream system of the dream-god Aesculapius stands over against another system, rational medicine, the ideas of which are associated with the great name of Hippocrates. That system is based on the collection and collation of experience. It is a steep and narrow way that has thus to be traversed, but one that the advancing ages have more and more fully justified. The other path has been trodden by countless millions throughout all human time. There has never

been an age when the practice of theurgy has not been widespread, and the overwhelming majority of mankind employs it to this day. It is the way of dreams! 'The gods sell us all good things at a price', said one of the wisest of the ancients. Science, the rational spirit, perceives that the price must be paid, and she pays it. She dwells now secure in her own house. Theurgy would get something for nothing. She is content with dreams; progress is unknown to her, and the path she has chosen leads back to the spot where her journey began. Her practices at this day differ not at all from those of ten thousand years ago. She still takes such refuge as she may find from the elements in the wretched hut which man first built for himself or for her—and in her dreams!

We gladly turn from the world of dreams to the actuality of the early development of scientific medicine. The calm and stately beauty of the best Greek medical writings stands out sharp and clear against the background of sombre folk-belief and priestly charlatanry. The noblest expression of early Greek science is undoubtedly to be found in the so-called *Hippocratic Collection*.

It will naturally be asked, 'Which of the works of this great collection is by Hippocrates himself?' and to that question, it must be feared, only a very disappointing answer can be given. There is not a single work extant which we can regard with certainty as by the father of medicine. Modern critical examination of the *Hippocratic Collection* has shown that the books of which it is composed are the work of a number of authors, belonging to different schools, holding various and often contradictory views, living in various parts of the Greek world and at dates widely separated from each other. We have no standard of genuineness whatever, and all that we can claim for some of the finest books of this collection, e.g. the *Aphorisms*, the work *On Wounds of the Head*, the

Epidemics or the *Prognostics*, is that they contain nothing inconsistent with a Hippocratic origin, that their ethical standpoint is in accord with the Hippocratic ideal, and that they are the work of a physician of great experience and intellectual power.

If we ask what is known about Hippocrates himself, the answer must be almost as meagre. We can be sure that he was a real person and not merely a mythical figure, for he is mentioned with high respect by his younger contemporary Plato. He was born at Cos about 460 B.C., the son of the physician Herakleides and his wife Phainarete. His most important works would thus begin to appear about 420 B.C. His death is placed between 377 and 359—the latter would make him 101, a very appropriate age for a great physician. He led a wandering life, and is heard of at Cos, Thasos, Athens, in Thrace and elsewhere, and lastly in Thessaly, where he died and where his grave is said to have long been shown on the road between Larissa and Gyrton. He had many pupils, among whom were his two sons Thessalos and Drakon and his son-in-law Polybos. Of the works of the latter we have fragments the genuineness of which is guaranteed for us by Aristotle himself.

That is all that is known with certainty about the father of medicine. We have not even his portrait. Yet we have something which for historical purposes is far better: we have an idealized representation of what the Greek would wish his physician to be. It is a noble bust to which the name of Hippocrates was early attached. Many copies of it exist, and to the calm, righteous, and dignified presence which it portrays, medical men will continue to pay homage.

But if critical examination has thus dealt with the Hippocratic writings and with Hippocrates himself, it may be asked what has been left which we may surely

derive from the Greek medical system? The answer is: two great things, the picture of a man and the picture of a method.

The man is Hippocrates himself. His figure, perhaps gaining in dignity what it loses in clearness, stands for all time as that of the ideal physician, for the ideal is there and is clearly set forth in these great writings, whether we discern the details of his features or no. Calm and effective, humane and observant, prompt and cautious, at once learned and willing to learn, eager alike to get and to give knowledge, but with a most profound reverence for the claims of his patient, zealous that his knowledge may benefit others—both the sick and their servants, the physicians—incorruptible and pure in mind and body, the figure of the greatest of physicians has gained, not lost, by time. In all ages the reverence of medical men for the greatest of their number has been comparable only to that which their followers have felt towards the founders of the great religions. The figure of Hippocrates has thus been of incalculable ethical and spiritual value in the twenty-three centuries that have passed since his death.

The method of Hippocratic medicine is that known to-day as the 'experimental' or better 'experiential'. It was followed among the Greeks for centuries after the death of Hippocrates. Then came a time when a great political, social, and philosophical upheaval prevented its further prosecution. For a thousand years after the break-up of the Roman Empire, the medical practice of Europe was at best a corrupted imitation and misunderstanding of the teaching of Hippocrates; at worst it descended to a low level of animism and magic. Then there was a rally, and slowly—very slowly and stumblingly at first—the foundations of modern science were laboriously laid. Among the first elements in this scientific

renaissance was the recovery of Hippocratic works, or of imitations of them. For some centuries more, his very words were taught in the medical schools in a spirit that was far from that of the master.

Gradually, however, a better understanding crept into men's minds. It was the spirit of those writings and their methods and observations that were now rightly emphasized rather than the works themselves. The works themselves began to drop out of the medical curriculum, and a first-hand knowledge of them is not now demanded in any medical school. But if we turn again to contemplate the Hippocratic treatises, we may still see at work the modern process of careful record of data and cautious inference from them, that progressive collation of experience with which we are now so familiar. We may see the actual process of case-taking, bedside-instruction, and clinical-lecture in full force, practised much in the manner which we know to-day, and described for us with a conciseness and beauty of language and a loftiness of ethical tone which have never been surpassed. Some of the Hippocratic works feel the most modern of all ancient writings. To such a collection medical men must always return. With a few extracts from three of these writings we may therefore most appropriately close our brief sketch of Greek medicine.

The *Hippocratic Oath* is a magnificent passage which, though usually included in the *Hippocratic Collection*, is certainly, in its present form, of much later date. Yet parts of it may be even earlier than Hippocrates, and some suggestion of it has been seen in the Ebers papyrus of about 1500 B.C. The first author who mentions the oath is, however, of the first century A.D. It need perhaps hardly be said that its late date by no means lessens the interest of this grand ethical monument. No passage better reflects the spirit of the Hippocratic physicians.

'I swear by Apollo the physician and Aesculapius and Hygieia and Panacea, invoking all the gods and goddesses to be my witnesses, that I will fulfil this Oath and this written covenant to the best of my power and of my judgement.

I will look upon him who shall have taught me this art even as on mine own parents; I will share with him my substance, and supply his necessities if he be in need; I will regard his offspring even as my own brethren, and will teach them this art, if they desire to learn it, without fee or covenant, and will impart it by precept, by lecture and by all other manner of teaching, not only to my own sons but also to the sons of him who taught me, and to disciples bound by covenant and oath according to the law of the physicians, but to none other.

The regimen I adopt shall be for the benefit of the patients to the best of my power and judgement, not for their injury or for any wrongful purpose. I will not give a deadly drug to any one, though it be asked of me, nor will I lead the way in such counsel; and likewise I will not give a woman a pessary to procure abortion. But I will keep my life and my art in purity and holiness. Whatsoever house I enter, I will enter for the benefit of the sick, refraining from all voluntary wrongdoing and corruption, especially seduction of male or female, bond or free. Whatsoever things I see or hear concerning the life of men, in my attendance on the sick or apart from my attendance, which ought not to be blabbed abroad, I will keep silence on them, counting such things to be as religious secrets.

If I fulfil this oath and confound it not, be it mine to enjoy life and art alike, with good repute among all men for all time to come; but may the contrary befall me if I transgress and violate my oath.'[1]

The *Aphorisms* is the most famous book with which the name of Hippocrates is associated. It is probably the greatest medical work ever written, and many think that of all the collection it is the one most likely to be really the

[1] This translation of the Oath has been prepared by Professor Arthur Platt.

work of Hippocrates himself. It consists of a series of very succinct generalizations. Many of these have been amply confirmed by the clinical experience of later ages, some have passed into medical commonplaces, yet others have become popular proverbs. The whole appearance of the work suggests an aged physician reflecting on the experience of a lifetime. Among modern medical writings its closest analogy is perhaps the *Commentary* of William Heberden the elder (1710–1801), one of the very greatest of British physicians. This remarkable work was commenced by Heberden after the age of seventy, occupied the last twenty years of his life, contained a summary of the whole of his vast experience, and was published by his son after his death. If the *Aphorisms* is similarly a work of the old age of Hippocrates, it may be dated about 380 B. C. The book is fortunately of such a character that a few extracts give a fair idea of its nature. We have here adopted a rough classification of some of the best known and truest of the Aphorisms.

General.

'Life is short and the Art [i.e. of Medicine] is long; the crisis is fleeting, experiment risky, decision difficult. Not only must the physician be ready to do his duty, but the patient, the attendants, and external circumstances must aid in the cure.

If in any illness sleep does harm, it is a mortal symptom.

Spontaneous weariness indicates disease.

The dry seasons of the year are more healthy than the rainy and attended by less mortality.

In cases of jaundice, induration of the liver is a bad sign.'

Age and Sex in relation to disease.

'Old people have for the most part fewer illnesses than the young, but if any illness becomes chronic with them they generally carry it with them to the grave.

Old persons bear fasting most easily, next adults, and

young people least; least of all children, and least of these, again, any who may be particularly full of energy.

Phthisis comes on mostly from eighteen to thirty-five years of age.

Apoplexy is commonest between the ages of forty and sixty.

It is fatal for a woman in pregnancy to be attacked by one of the acute diseases.'

Nutrition in disease.

'If you give the same nutriment to a patient in a fever and to a person in health, the patient's disease is aggravated by what adds strength to the healthy man.

Any food or drink slightly inferior in itself, but more pleasant, should be preferred to those which are better in themselves, but less pleasant.

To eat heartily after a long illness without putting on flesh is a grave sign.'

Signs connected with fevers and convulsions.

'Convulsions supervening on a wound are deadly.

Those attacked by tetanus either die within four days, or, if they get through these, they recover.

Cold sweats in conjunction with an acute fever indicate death, but with a milder fever only prolonged sickness.

Fever following a convulsion is better than a convulsion following a fever.'

Certain fatal signs.

'We should observe the appearance of the eyes in sleep; if any of the white show through the eyelids when closing, this is a bad sign and very dangerous, unless it be due to diarrhoea or taking a purgative.

Those who have severe fainting fits die suddenly without apparent cause.

Those who are naturally very fat are more liable to sudden death than the thin.'

The *Prognostics.* Immense, and, as some may think, overwhelming, importance is attached in the Hippocratic writings to the art of prognosis or foretelling the course

and duration of a disease. The work to which the title *Prognostics* is attached represents a very lofty standard of practice, but we have only space to quote a single typical and famous passage. It is a description of the signs of death to which the name of *Hippocratic facies* has become attached. It is imitated by Shakespeare in his description of the death of Falstaff in *Henry V*.

'You should observe thus in acute diseases: first the countenance of the patient, if it be like those of persons in health, and especially, if it be like itself, for this is best of all. But the opposite are the worst, such as these: a sharp nose, hollow eyes, collapsed temples; the ears cold, contracted, and their lobes turned out; the skin about the forehead rough, stretched, and parched; the colour of the face greenish, dusky, livid, or leaden.

If the countenance be such at the beginning of the disease, and if this cannot be accounted for by the symptoms, inquiry must be made whether the patient has been sleepless, whether his bowels have been very loose, and whether he has wanted food, and if any of these be confessed the danger is to be reckoned so far the less, and it will become obvious in a day and night whether or no the appearance come of these. But if none such cause exist and if the symptoms do not subside in this time, be it known for certain that death is nigh.'

§ 4. *Medicine and the Empire*

Scientific medicine in Antiquity was, as we have seen, essentially a product of the Greek genius. It was closely related to and in its turn reacted upon the philosophy of the age. Later, in the Hellenistic period, scientific medicine was more and more developed as a special department which demanded early and prolonged apprenticeship. The subject of study of the Hippocratic physicians thus became in Alexandrian times crystallized into a definite discipline. In the hands of Herophilus, Erasistratus, and their followers, the foundations of

anatomy and physiology were laid in the third century B.C. Encouraged by the Ptolemaic dynasty, medical knowledge continued to advance along academic lines, and Alexandria remained the chief centre of medical study for long after 30 B.C. when Egypt became a Roman province.

The inclusion of Egypt within the Roman Empire, however, was to have a very far-reaching effect on medicine. The Roman people never developed scientific tastes. Even a real comprehension of the scientific standpoint was excessively rare among them, and no man of Roman blood ever wrote an important medical work. The Romans, nevertheless, were by no means slow to appreciate the advantages to be derived from medical science and to utilize Greek medical talent. Indeed, with the exception of the *Hippocratic Collection* practically all the works of ancient medicine that have come down to us were produced by Greek physicians within the Empire. Among the most eminent of these were Soranus of Ephesus, who lived in the second century A. D. and wrote scientific treatises on anatomy, midwifery, and medicine, and Dioscorides of Anazarba in Cilicia, who lived in the first century A. D., was a military surgeon under Nero, and wrote the most influential botanical treatise ever penned. Dioscorides has deeply influenced modern botanical nomenclature, and many of our popular plant names are to be found in his work. A word must also be said concerning the medical work to which the name of Celsus is attached. It is thoroughly scientific and is the only important ancient medical treatise in Latin. A large part of the work is surgical, and it is our best representative of the surgery of the Alexandrian School. There can be no doubt, however, that it is an adaptation from the Greek, and not an original composition. It was the first ancient medical treatise to be printed (Florence 1478).

Towering above all the other physicians who practised in the Empire stands the mighty figure of Galen (130–201). He was physician to Marcus Aurelius, and left behind him a truly portentous mass of literary material. Galen was a highly cultivated man, an experimenter, a most expert anatomist and physiologist as well as a capable and shrewd physician, and a teacher of no mean order, but as a writer garrulous and diffuse to the last degree. His anatomical and physiological views, in more or less corrupted form, held the field in the mediaeval world—both Oriental and Occidental—until the coming of Vesalius and Harvey.

The genius of Rome lay in organization rather than knowledge, in discipline rather than science. Many centres of medical teaching sprang up in the Empire at Pergamum, Rome, Beneventum, Marseilles, and elsewhere, but the contributions of these schools to scientific medicine were very small. Though Galen himself was born in Pergamum he studied in Alexandria, and that city retained the lead to the end. There were two departments of medicine, however, in which the peculiar Roman capacity found fuller scope. These were preventive medicine and the organized treatment of disease. Sanitation is largely and the hospital almost entirely of Roman invention.

The sanitation of Rome was a natural outcome of the sense of public duty so carefully instilled into its citizens. The *cloaca maxima*, the main drainage conduit of the city, dates right back to the Tarquins (*c.* 590 B.C.). The idea was almost certainly derived from the Etruscans. Sewers, as we have seen, are also encountered on Minoan sites long anterior to Roman times, and there are very evident sanitary enactments in the Bible. But the general and organized public care for sanitation, combined with the formation of structural sanitary devices on

a large scale, is peculiarly Roman and is a product of the characteristic Roman attitude to life.

Here too something must be said of the wonderful arrangements for water supply that were made throughout the Empire, but most characteristically in Rome itself. The great aqueducts of Rome are said to have brought to the city about 300,000,000 gallons of water a day. Modern sanitarians regard 30 gallons per head per day as a reasonable supply. Thus the Roman aqueducts would have been adequate for about 10,000,000 souls on modern computation. The population of the great city can never have approached this number. The very full supply can be doubtless explained by the Roman love for the bath.

Perhaps an even more characteristic product of the Roman genius was the hospital system. State physicians are early mentioned as paid out of public funds. Before the days of the Empire, the Greek physicians had possessed private surgeries or even something approaching to nursing homes. With the expansion of Rome, however, with the wars on her frontiers, with the massing of sick and wounded troops, new needs arose. The Romans early instituted *valetudinaria* or hospitals for soldiers at their great military dépôts. The sites of several of these military base-hospitals, dating from the first century of the Christian era, have been excavated.

From the military *valetudinaria* it was no great step to the construction of similar institutions for the numerous imperial officials and their families in the provincial towns. Motives of benevolence, too, seem to have gradually come in, and finally public hospitals were founded in many localities. The idea naturally passed on to Christian times, and the pious foundation of hospitals for the sick and outcast in the Middle Ages is to be traced back to these Roman *valetudinaria*.

The first of these Christian institutions concerning which we have clear information was established at Rome in the fourth century by a lady named Fabiola. Our knowledge concerning it comes to us from St. Jerome. The actual plan of a hospital projected at St. Gall in the early years of the ninth century has survived. It reminds us in many respects of the plan of the early Roman military hospitals. These mediaeval hospitals for the sick must naturally be distinguished from the even more numerous mediaeval 'hospitals' or 'hospices' for travellers and pilgrims, the idea of which may also be traced back to the rest-houses along the strategic roads of the Empire.

But if, with the passing of antiquity and the advance of Christian sentiment, the sick became more widely cared for, it is certain that the care was ever less and less efficient. From the later days of the Empire a number of medical writings have come down to us. They give a reflex of those exclusively *practical* interests which mark the new limitation of the human intellect.

With the spread of Christianity, interest in phenomena had dwindled. The light of science had become dim, then flickered, and finally went out. Medicine alone survived—but how changed! In the absence of any theoretical interests, medical knowledge had progressively deteriorated. The anatomical, physiological, and pathological bases of medical knowledge were more and more disregarded. The later Latin medical works were thus reduced to mere lists of remedies, and entirely ignore theory. All such arbitrary treatments of mental needs bring their own nemesis. Such works from being practical become empirical, from empirical they pass to being merely rule-of-thumb, then corrupt, and finally basely superstitious. Before the process was ended, learned and Christian physicians had attached

their names to material as mean and debased as any which the field-anthropologist has elicited from the lore of the lowest savages. From Hippocrates the Great of Cos to Marcellus Empiricus of Bordeaux is eight hundred years. The difference in outlook between the two is as the difference between the practice of Lister and the lowest type of magic. The discussion of the long weary process of elevation from that miserable slough must be reserved for another chapter.

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III

ASPECTS OF BIOLOGICAL AND GEOLOGICAL KNOWLEDGE IN ANTIQUITY

Arthur Platt

It is a curious thing in this age, when science is supposed to have become a popular subject, that so few classical scholars take any interest in it. Perhaps it may be said that there is a natural division, a great gulf, between the arts and sciences, and that for one to try and communicate with the other is as unsatisfactory an enterprise as that of Pyramus and Thisbe whispering to one another through a chink in the wall between their respective parents' estates. But if there is one thing more clear than another it is that there is really rather a connexion than a wall between them. Look at Goethe, Redi, Tennyson, and many others—and were not Gesner and Spallanzani professors of Greek?

Besides, many of us are brought up to study the early developments of Greek science. We are laboriously dragged through the conjectures of Anaximander and Democritus, and very interesting and prophetic those conjectures are. But when science gets out of the first stage of conjecture and becomes really science worthy of the name, there we stop all of a sudden. It is surely rather absurd to be interested first in the guesswork of the pre-Socratics and then to avert one's eyes from the really important scientific work done by Hippocrates and Aristotle. Even such a simple matter as the explanation of references to ordinary observation of plants and animals by the great writers is sadly neglected. It is really comical to see how a classical editor will turn tail and bolt for his life at the mention of a beast or bird,

while he will gallantly face a problem of Athenian law or of the details of a Roman army. And yet sometimes this results in melancholy misunderstanding of important passages. For instance, there is a passage in Aeschylus about two eagles, one black, the other white-tailed. The multitudinous commentators have never asked what these were; if they had they would have found that Aeschylus was thinking of a mature golden eagle (called black eagle in Scotland to this day) teaching its young one (which *has* a white tail) to prey, and this clears up the meaning of the whole passage.

But it is time to come to business. Natural science really began by careful observation of two things, the stars of the heaven and the bodies of men. Of astronomy I do not purpose to say anything; Sir Thomas Heath has written an admirable history of it among the ancients in his introduction to Aristarchus of Samos. Nor is there time, nor have I the power, to go through the history of medicine; but I will just take two or three points of interest.

We all say that we think with our brains, and it has become so natural to us to believe this that we can hardly conceive that anybody ever thought anything else. Yet that is not the natural idea of the natural man—very far from it. The savage feels his heart beating and he inevitably assumes that the seat of life and all vital powers, including the intellect, is in the heart. The Bible assumes that all through, and so does early Greek literature, and so we still talk of the heart as the seat of the affections, though we may not call it the seat of the intellect. Another theory was that the kidneys were the brain, so to say; that also appears in the Bible.[1]

If you come to think of it, the greatest discovery ever

[1] Psalms 16. 7.

I will bless the Lord, who hath given me counsel:
Yea, my reins instruct me in the night seasons.

made in physiology was this, that the brain is the organ of sensation and thought. We should be ashamed not to be able to say who discovered the circulation of the blood; how many of us can say who discovered the use of the brain? Well, it was Alcmaeon of Crotona, who, I think, must have been a very great man. Alcmaeon, it seems, observed that the sense-organs were all somehow connected with the brain, and made the great advance of saying that the brain was that by which we feel. Whether he went on to say also that we think with it, is not quite clear; but it seems from a passage in the *Phaedo* of Plato that he did, and it is indeed hard to see how he could help going on to that.

Once this was established, it remained a fixed doctrine in the great medical school. Hippocrates assumes it as a matter of course. It had become the popular view at Athens before the end of the fifth century, as we see from Aristophanes, when Strepsiades says sarcastically of a man at the end of the *Clouds*: 'he seems to me to have got concussion of the brain', and Hegesippus (in the speech on Halonnesus attributed wrongly to Demosthenes) says 'if you carry your brains in your skulls and not trampled down in your heels'. Plato also assumes it in *Timaeus*, but you must not give him any particular credit for it; remember always that Plato took all his physiology straight from Hippocrates.

But what *is* astonishing is the view of Aristotle. He was the son of a physician and brought up in contact with physicians. They all said, and everybody knew, even the man in the street, that we think and feel with our brains. How amazed we are then to learn that Aristotle defied the medical school and went back to the old old notion that sensation and thought are located about the heart. It is the most wonderful retrogression perhaps in the whole history of science. If the Astro-

nomer Royal were suddenly to tell us that after all the sun does go round the earth, we should begin to think of calling in a mad-doctor to see whether he ought not to be shut up in a lunatic asylum. Aristotle's case is like that; he was incomparably the greatest biologist of his time, perhaps the greatest of all time, and he seriously said that the heart was the seat of sensation and of thought. How, you ask, did he come to entertain so ludicrous a view, to dig up again the dead and rotting theory of the primitive savage and present it for the acceptance of civilized and cultivated men?

The answer may sound as astonishing as the puzzle itself. Aristotle did this just because he was a great master of science and because he had made a very great discovery. He practised vivisection, and he had found out that if you cut or burn the brain it does *not* feel. What was he to say to this? On the face of it, it was a knock-down blow to the medical theory. If the brain cannot feel, why say that it is the seat of sensation? And if not of sensation, then not of thought either, for all thought comes from sensation. I think it probable also, though this is only a guess, that he had discovered that the brain of an animal can be removed without destroying life, whereas to injure the heart causes death at once, and so he surely could not help placing life, sensation, thought, all together in the heart. And he had seen the heart appearing as a *punctum saliens* in the chick before there was any sign of a brain.

But Aristotle was never content without a theory about everything; it is a weak point in him, as in everybody, until they have been much chastened by the experience of generations; lucky if then! So he invented a theory, a very bad one. He assumed the brain to be cold and watery, and decided that it existed as a regulator to cool the heat of the heart, which otherwise would kill us right

away. Man as the most perfect of animals is also the hottest (which is not true, but Aristotle had no clinical thermometer): therefore he requires the largest brain to counteract the heat. And so through the whole scale of animal life, the higher the animal the bigger refrigerator is required. That Nature should first make such a furnace in us and then squash it again by such a sponge of cold water (as Galen ironically calls it) rather suggests the old man who had a plan to dye his whiskers green and always used so large a fan that they could not be seen. But it seems that we need a most dangerous fire in us to enable us to think and carry out the higher vital functions, and so Nature could not help herself.

The medicals appear to have remained obstinate; they did not like Aristotle, I fancy, regarding him as a meddling amateur. And they presently proved their case against him. The greatest name in physiology between Aristotle and Galen is that of Erasistratus of Alexandria. He is principally known, perhaps, because of his theory that the arteries contain *only* air, not blood. You will find it frequently stated in modern books that this was the general opinion among the ancients: do not believe it. Nobody ever said so before Erasistratus, neither Praxagoras nor Diocles nor the Ebers papyrus; at least I cannot see that there is any evidence for attributing it to them. The papyrus says that the arteries contain milk and half a dozen other things: this is not to say that they contain nothing but air. It seems an astonishing theory to put forward, but Huxley declares that it was an exceedingly reasonable view in the then state of knowledge, and that Erasistratus was naturally driven to it. It held its own till towards A. D. 200, when Galen decisively disproved it by experiment on living animals. But the really great work of Erasistratus, which he shared with his contemporary Herophilus, was that on the nervous system.

It is thought that Aristotle discovered the *optic* nerves, but he almost certainly knew no others, nor did he appreciate the use of even the optic nerve, which he called simply a passage between eye and brain. The medical men, once the nerves began to be explored, soon found that they conveyed sensation to the brain, and so Aristotle's views on the brain fell into a peaceful oblivion.

The last of this succession of neurologists is Galen, and his researches on the nervous system are reported to be his great glory. 'I am fond of referring to Galen', said Sir Victor Horsley, 'because it is perfectly astonishing what an amount of accurate neurological knowledge Galen acquired by his experiments on the lower animals and demonstrated to his pupils in Rome.'

I must content myself here with repeating that Galen's knowledge of the nerves marks the high-water point of ancient science in that direction. About 200 he died, and then set the sun of science till its glorious resurrection in the year 1543. For thirteen centuries and a half hardly a step forward was taken in anatomy of any sort or kind, nor in any other science except a few observations in chemistry and astronomy.

It is interesting to contemplate the dates and the discoveries in this history.

c. 500 B.C.	Alcmaeon discovers that the brain feels and thinks.
c. 350 B.C.	Aristotle points out that the brain cannot feel anything directly.
c. 300 B.C.	Herophilus and Erasistratus discover the nervous system.
c. A.D. 180.	Galen.

So in 700 years there are only five names of any great consequence, and after that a blank silence. Yet what

a prodigious advance had been made by just those very few investigators.

Two questions naturally arise. Why were there so few? and why this sudden stop? There was no lack of brains during these 800 years, and if advance depended on isolated geniuses it is clear that the reason why the advance goes in great jerks at such long intervals is probably due to the want of method and of training. Of the importance of that the ancients had no idea whatever. If we depended now on single geniuses cropping up without anything to direct them we should not get on much quicker than did the ancients. And if you want to know why science came to an end altogether about A. D. 200, read first the correspondence of Cicero and then that of Fronto. In the former you are in an atmosphere of intellectual power, activity, insight; not only Cicero himself, but all his multitudinous correspondents, strike one in that way. In Fronto's correspondence you find the first literary man of his time and the people at the head of politics talking like a lot of idle old women, and the atmosphere that of a ladies' tea party.

But let us take another curious question of physiology. You doubtless remember a fragment of Alcaeus which begins: 'Bedew your lungs with wine, for the Dog-star rises again.' One reads it languidly supposing lungs to be poetic licence. No such thing. In a work in the Hippocratic collection you will find the same thing seriously stated as a fact, that the solid food indeed goes into the stomach, but liquid into the lungs. Plato of course repeats the lesson in *Timaeus*. But Aristotle proves quite clearly that the liquid as well as the solid goes to the stomach, and he is very angry with those who deny this—'but perhaps it is silly to argue against such silliness', says he. It is a wonderful thing that it should have been left to Aristotle to make this advance, and it shows again

how deficient the ancients were in encouraging any general spirit of investigation, and how dependent their science was upon an isolated genius arising here and there. But it is more wonderful still to find Galen 500 years later still seriously discussing the question; he knows that Aristotle is right, but cannot find it in his heart to throw Hippocrates and Plato over altogether, and he actually ends by saying that after all perhaps *some* of the liquid goes into the lungs. Respect for authority was nearly as ruinous then as it was among the conservative idiots at the revival of science who preferred Aristotle to demonstrated facts.

Here again we find Aristotle in the van of progress. And wherever you look in biology, he is first and midst and without end. So far as we can tell there was no biology before him worth looking at. Just as he created logic as a full-blown science springing in full armour out of his head, so he created embryology and comparative anatomy; he had no forerunners and no successors in these subjects worth looking at so far as we know. 'Never', it has been said, 'did any science leave its creator's hands so fully equipped as that of comparative anatomy.' The germ from which it sprang was to be seen in the famous sentence of Anaxagoras: 'Mind ordered Chaos for a good end.' Plato, *not* Socrates, says in *Phaedo* that he tried to apply this principle to Nature but failed to do so; later on in *Timaeus* he does apply it in a way to human physiology. Aristotle in *De Partibus Animalium* first applies it to the whole world of animal life, comparing the use of a bird's wing, for instance, and that of a reptile's fore leg, pointing out how the structures vary in accord with the uses required of them, and thereby created the science which has now been developed to such vast proportions. In so doing he lays down one great law after another; here is a list of some

of them as given by Dr. Ogle in his most interesting introduction to his translation of the treatise.

1. The law of organic equivalents—that Nature must save in one part if she spends in another.
2. The advantage of physiological division of labour.
3. Complexity of life varies with complexity of organization.
4. No animal has more than one adequate means of defence.
5. Inverse relation between development of horns and teeth.
6. No dipterous insect has a sting.
7. Inverse relation between growth and generation.
8. Development of embryo from homogeneous to heterogeneous.
9. Development is progress from general to special form.

Of course there are innumerable mistakes in the book, but it would be pitiful to lay stress upon them; there were great mistakes in *The Origin of Species*. But listen to what Darwin himself said when he first saw Aristotle's work: 'Linnaeus and Cuvier have been my great gods, but they are mere schoolboys to old Aristotle.'

Great as the *De Partibus* is, it is cast into the shade by its sister work, that on the Generation and Development of Animals. George Henry Lewes, known now I suppose principally in connexion with George Eliot, wrote a book called *Aristotle*, which really means *Aristotle's Science*: it is a most malignant work, directed all through at running Aristotle down. I owe a great deal to it myself, because it was getting hold of it by chance when I was an undergraduate, and ought to have been reading other things, that first interested me in the whole business, not only in animals, but also modern science. And Lewes had great provocation because of the absurd way in which certain uncritical men of science had told falsehoods

about Aristotle, enormously exaggerating his merits. For all that it is not a good book, and its animus against the mighty master is deplorable. Well, when Lewes comes to the *De Generatione* he cannot hold out any longer; he is as hyperbolical in praise of it as Cuvier himself. He declares that in philosophical grasp Aristotle greatly surpasses even the immortal Harvey. For Harvey is the second great name in embryology; we have to jump over very nearly 2,000 years before Aristotle found a successor in this. And it is a fact that Aristotle was in certain points ahead of not only Harvey, but *all* modern science till about the year 1900. Few questions have been more often discussed than the question why some children are male and some female. Reckless guesses were put out as facts by Empedocles, Parmeneides, and other people in the days of Greek philosophy; one theory after another goes on being made now. One favourite view was that it was connected with nutrition; feed the mother up before the birth and you will get a girl, starve her and you will get a boy. It never seems to have struck these amiable speculators that if that were so more boys ought to be born among the poorest classes and more girls among the richest. But what I call your attention to is this: speculations of this kind assume that the sex of a child can be determined at quite a late period of embryonic development. Now Aristotle asserts, and he not only asserts but proves as plainly as a proposition in Euclid, that sex is determined in the embryo of the chick as early as the third day after the egg begins to develop. Yet in spite of this proof, people went on talking about the importance of nutrition in this business right up to about 1900. I dare say some do so still, though Mendelism has finally knocked the notion on the head.

It is in such passages as these that we see Aristotle at his very best. Where pure intellectual power, grasp,

insight are required, no modern can surpass him. And he is great as an observer too, and well aware that speculation must be tested by observation. There is a somewhat famous paragraph on this head in the *De Generatione.* After discussing at great length the question of bees, and hitting, by the way, upon the truth that bees may produce drones parthenogenetically, he concludes thus:

> 'Such appears to be the truth about the generation of bees, judging from theory and from what are believed to be the facts about them; the facts, however, have not yet been sufficiently grasped; if ever they are, then credit must be given rather to observation than to theories, and to theories only if what they affirm agrees with the observed facts.'

The quantity of things Aristotle had spied into is truly extraordinary: he knew that certain sharks have a kind of placenta, a thing found elsewhere only among the higher mammalia, and this was not re-discovered by the moderns until Johannes Müller reaffirmed it in 1840; he knew that the yolk of the egg liquefies during incubation, a thing of which I found the modern zoologists to be completely ignorant. He knew which way up a hen lays her egg—do you? And the way in which Aristotle argues upon general questions of embryology is quite astounding, though he was too hasty in generalizing, and he did not understand the importance of experiment. He could observe with the naked eye as well as anybody, but it had not then dawned upon people that mere observation by itself is of comparatively little use. And the naked eye is a sadly deficient instrument. The grand reasons why modern science has advanced so much farther than ancient appear to me to be these: recognition of the importance of experiment, the habit of testing hypotheses (which Aristotle might have learned from

Socrates), the invention of the microscope and the telescope and other instruments of all kinds, and the training of a multitude of men in scientific methods. None of these things were to be found among the ancients; they trusted at best to observation and arguments upon their observation. In this they went as far as it was possible for man to go.

A good instance of this may be seen in the scattered speculations upon geology. It is delightful to see how free and unfettered in their mental outlook the ancients were as compared with many modern writers, who not so very long ago did not dare to go beyond a paltry 6,000 years for the history of the earth. Herodotus sees plainly that Egypt is the gift of the Nile, and guesses that if the Nile were to be diverted and flow into the Red Sea, it would fill it up in 10,000 years. Plato looks back into vistas of time which go far beyond this. He thinks that many past civilizations have been wiped out by great geological catastrophes. The inhabitants of the earth were consumed by deluges or earthquakes; only a few escaped, and had to begin again laboriously building up a new civilization. And the more we get to know about prehistoric archaeology, the truer this turns out to be. At least we see dimly one civilization under another, only we no longer believe that they were destroyed by earthquakes and volcanoes and inundations, but by the still more ruinous and detestable agency of war. But the great triumph of Plato in this connexion is his speculation on the past state of Greece and the Aegean. The rocky hills of Greece and the islands, he says, are like the bones of a body wasted with disease. But in the past they were clothed with a rich mantle of earth and covered with vegetation and forests. Very likely it is largely a lucky guess, but modern geology confirms it. In the Miocene period Attica and the islands of the Aegean

really were a rich country, abounding in mammalian life; all over the Aegean spread a land of rolling grass plains and woods supporting antelopes, a sort of giraffe, apes and all sorts of animals; it has now largely sunk below the sea-level, and its relics have been reduced by the action of sub-aerial denudation to the state in which we now see them, the skeleton of a body wasted by disease, as Plato puts it.

The first book of the *Metamorphoses* of Ovid also shows an astonishing insight into geology, not of course on the part of the poet himself. No Roman ever had any insight into scientific questions; like Lucretius and like the elder Pliny, Ovid merely repeats what he had got from the Greeks. The discourse upon geology which occupies a large part of the 15th book of the *Metamorphoses* is put into the mouth of Pythagoras, and apparently represents the teaching of a Pythagorean school.

> Vidi ego quod fuerat quondam solidissima tellus
> Esse fretum; vidi factas ex aequore terras
> Et procul a pelago conchae iacuere marinae.

This presence of shells in deposits raised high above sea-level has always been one of the phenomena most calculated to make people think. When the Italians again took up the torch of learning, it was just this phenomenon about which they began to argue, and it is a matter of particular interest to observe that the two greatest men who insisted on the correct interpretation of it were no others than Leonardo da Vinci and Fracastoro, the celebrated doctor and writer of Latin verse. But besides the marine shells Ovid mentions a great number of other pieces of evidence that the surface of the earth is continually changing.

Strabo discusses the question of the shells with wonder-

ful insight. He lays down the principle that we ought to explain such obscure questions by appealing to things that are obvious and in some measure of daily occurrence, and this is exactly the principle which was worked out so triumphantly by Sir Charles Lyell. And so he explains the presence of the shells by saying 'the same land is sometimes raised up and sometimes depressed, and the sea in like manner is sometimes raised and sometimes depressed, so that it either overflows or returns to its own place'. Much more remarkable, I think, is his observation that 'volcanos are safety-valves, and that the subterranean convulsions are probably most violent where first the volcanic energy shifts itself to a new quarter' (Lyell).

But in general we see here the same phenomenon: the ancients observe acutely, but it is by fits and starts; they reason acutely upon their observations, but they do not advance. There is no organized body of investigators taking up and working at innumerable small points, as there is now, and there is no attempt at making any kind of experiment, such as those of Hutton at the end of the eighteenth century. And it is a very curious thing that they paid no attention whatever to the fossil remains of animals. Yet such remains were of course known to them. Suetonius in his Life of Augustus 72 tells us of bones of monstrous beasts found in the island of Capreae and elsewhere, which were called 'bones of giants' and 'arms of the Heroes'. Such bones were pointed out in the island of Elba, and were there called the 'arms of the Argonauts', as we learn from Apollonius Rhodius. You would have thought that these remains should have aroused more interest, but it seems that the untrained and unscientific mind altogether fails to be impressed by them. In the Middle Ages a thigh bone of an elephant was carried in procession through the

streets of Rome, and worshipped as a relic of St. Peter, if I recollect aright. The bones which Herodotus tells us were conveyed from Arcadia to Sparta as the bones of Orestes were probably something of the same kind. The word giant is said to mean 'earth-born'; were not the stories about the giants who fought the gods, and were overwhelmed and buried beneath the earth, due to the discovery of great bones of animals? But it is strange that nobody ever seriously asked what these bones had belonged to, or made any speculations about them. Comparative osteology is a very recent science; even Aristotle, profoundly interested in comparative physiology and anatomy as he was, never did anything worth speaking of in osteology, and in quite modern times a gigantic extinct salamander was described by its discoverer as 'homo diluvii testis'.

If these disconnected remarks lead any of you to follow up these questions, he will find himself amply rewarded.

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IV

GREEK MATHEMATICS AND ASTRONOMY

J. L. E. Dreyer

Long before mathematics began to be studied among the Greeks, geometry had been cultivated in Egypt. In that country, where the annual rise of the Nile obliterated all landmarks, it was an absolute necessity to have the means of recovering these by measurement and calculation. The word 'geometry' or earth-measurement plainly points to the practical application of the new science. How great was the value of the rules of land-surveying found by the Egyptians is shown by the fact that long after the Greeks had developed geometry into an important science, it was still mostly the Egyptian rules which were used by the Roman agrimensores, who no doubt knew little or nothing of the proofs of the rules found by the Greeks. The determination of areas was also an important problem in Egypt; but approximate solutions were generally considered good enough. The construction of the pyramids shows, however, that the Egyptians were capable of doing work which involved both careful measurement, as these monumental buildings were accurately oriented, and also some knowledge of similarity of figures, which is implied by the use of the ratio of half the side of the base to the height. In an Egyptian tomb of which the decoration is unfinished, a wall, on which a certain picture was to be copied on a different scale, has been divided into squares by two systems of parallel lines, which also implies the idea of similarity.

Apart from these and other practical rules, such as the construction of a right angle by making a triangle with sides equal to 3, 4, 5, the Greeks learned nothing in the way of mathematics from the Egyptians. Neither did they owe anything worth speaking of to the Babylonians. Although the latter people during the last few centuries before our Era (if not somewhat earlier) had attained a considerable amount of knowledge of the periods of revolution of the sun, moon, and planets, they reached this solely by the use of empirical formulae and never employed geometrical constructions. Mathematics is therefore in its origin a Greek and not an Oriental science.

Thales, the earliest philosopher of Greece (flourished about 600 B.C.), was a native of Miletus, one of the Greek colonies on the coast of Asia Minor. It is a remarkable fact, that all the early philosophers came from the outlying colonies and not from Hellas or Peloponnesus; as if the scanty Greek populations living next door to hostile nations had had their wits sharpened by this contact, as well as by having access to the knowledge gathered by them. Thales is also supposed to have travelled in Egypt, and may thereby have been stimulated to pay attention to geometry. Various theorems of the first book of Euclid are attributed to Thales: that the angles at the base of an isosceles triangle are equal (I. 5); that if two straight lines cut each other, they make the opposite angles equal to each other (I. 15); that if two triangles have two angles and one side respectively equal, the triangles are equal in every respect (I. 26). He is also said to have been the first to find that the angle in a semicircle is a right angle (Eucl. III. 31).

This was the small beginning of Greek mathematics, strict logical proofs taking the place of the Egyptian empiric rules and unproved (though sometimes correct) assertions. The next steps were taken by Pythagoras

(about 530 B.C.), but it is often difficult to say whether the credit of a discovery should be given to him or to some member of the philosophical school founded by him. The famous theorem Eucl. I. 47 is, however, generally credited to Pythagoras himself. His school discovered that the side and the diagonal of a square are incommensurable, a most important discovery. More generally known is the great discovery of Pythagoras, that the harmony of musical sounds depends on regular intervals corresponding to certain arithmetical ratios between lengths of string, the octave corresponding to the ratio 2:1, the fifth to 3:2, &c.

We must pass over 150 years before we come to another great mathematician, Eudoxus of Knidus in Asia Minor (about 380 B.C.). To him is due the theory of proportion, applicable both to commensurable and incommensurable quantities, set forth in the fifth book of Euclid. Also the so-called method of exhaustion, by means of which many problems of mensuration could be solved without the aid of infinitesimals. Eudoxus made use of this method to show that the volume of a pyramid (or a cone) is $\frac{1}{3}$ of that of a prism (or cylinder) on the same base and of equal height.

We have now reached the time when regular text-books began to appear. Autolycus of Pitane wrote 'on the moving sphere' and 'on risings and settings', dealing with various problems of spherical geometry suggested by the apparent phenomena of the starry heavens. Euclid, about whose life next to nothing is known, flourished about 300 B.C. He is of course best known to fame as the author of an immortal text-book; but he was also an original investigator to whom we owe the current arrangement of mathematical material, and who published other writings of value. Before Euclid died, Archimedes, the greatest of all the Greek mathematicians, was born

at Syracuse in 287 B.C. He was killed in his native city in 212 B.C., when it was captured and sacked by the Romans. He wrote a number of essays on almost every branch of mathematics, and his treatment was always original and threw new light on the subjects investigated. As regards geometry he showed that the ratio of the circumference of a circle to the diameter (now known as π) is less than $3\frac{1}{7}$ and greater than $3\frac{10}{71}$. He also developed Eudoxus' method of exhaustion and applied it to the determination of areas of a parabolic segment and a spiral. His method is really nothing but the modern integral calculus. He wrote a work on statics, particularly on the principle of the lever and on finding the centres of gravity of plane laminas. But better known than any of his other works is that on floating bodies, which is the first attempt (and a very successful one) to apply mathematical methods to problems of hydrostatics. Eighteen hundred years were to elapse before any advance was made on Archimedes' theories of the lever and of hydrostatics.

The last great mathematician we shall mention in this rapid review is Apollonius of Perga who lived about 230 B.C. and was therefore a contemporary of Archimedes). He spent most of his life at Alexandria, first as a student and in later years probably as a teacher in the Museum. Of his great work on Conic Sections in eight books the last is lost, and Books V, VI, VII are only extant in an Arabic translation. The work contains a very thorough and very complete investigation of the properties of these curves; so complete indeed, that it has been suggested that Apollonius must have found some of these properties by the use of coordinate geometry, and afterwards translated the proofs into a geometrical form. In any case the work stands in the foremost rank of mathematical publications of all ages.

We shall not follow the development of Greek Mathematics farther. We have shown how far it had advanced by the beginning of the second century B.C., and the means which thus had been placed at the disposal of astronomers were indeed amply sufficient to enable them to solve such problems as might arise in interpreting the observations made with their crude instruments.

Almost all the pre-Socratic philosophers speculated freely about the construction of the world, but, with the exception of Pythagoras and his school, they were not equipped with a sufficient amount of knowledge of observed facts to do so successfully. Pythagoras was the first to realize that the earth is a sphere, and he is credited with the discovery that the morning and evening stars are one and the same body. Either he or his younger contemporary Alcmaeon first taught that the sun, moon, and planets move in separate orbits from west to east. But all the celestial bodies were seen to partake of a common motion in the opposite direction; from east to west, as if the whole celestial sphere rotated in twenty-four hours from east to west. It was probably a feeling that all celestial motions ought to take place in the same direction which made Philolaus, a Pythagorean philosopher of the fifth century B.C., propose a very peculiar system of the world. According to this, the earth travelled in twenty-four hours from west to east in an orbit round a body called the central fire. Nobody had ever seen that body, but that was easily explained by assuming that the known parts of the earth, Greece and the surrounding countries, are situated on the side of the earth which is always turned away from the centre of the orbit. During the daily revolution a point on the earth's equator would in succession face every point on the celestial equator, thus producing the same effect as if

the earth merely rotated on its own axis. Moon, sun, and five planets all moved round the central fire in the same direction but in different periods, the moon in $29\frac{1}{2}$ days, the sun in a year. Day and night were easily accounted for; when the inhabited part of the earth swings round in sight of the sun we have day, and when it is carried round to the other side of the central fire, away from the sun, we have night. Similarly the system readily explains the revolutions of the moon and planets and the annual motion of the sun in the zodiac, as well as the changes of the seasons caused by the inclination of the sun's orbit to the equator, in the plane of which the earth moved. The visible celestial bodies were nine in number, the earth, the moon, the sun, the five planets and the sphere of the fixed stars. To complete the 'perfect number' of the Pythagoreans, Philolaus postulated a tenth body, the antichthon or counter-earth, which moves inside the earth's orbit and in the same period, so that it is always between the earth and the central fire and therefore invisible to us.

This system of the world does not appear to have won any adherents outside the philosophical school in which it originated, as it required a very strong faith to accept the doctrine of an unseen central body, of the existence of which there was no evidence anywhere, except perhaps the feeble light over the whole surface of the moon when only a couple of days old, which we now know is sunlight reflected from the earth. But the system paved the way for the simpler and more natural conception of the earth's rotation on its own axis. This step was taken by two Pythagoreans, Hiketas and Ekphantus, both of Syracuse, and the doctrine of Philolaus was also modified by substituting for the central fire the fire in the interior of the earth. We shall see presently that the doctrine of the earth's rotation was later on

revived by some powerful minds outside the Pythagorean school.

It was natural that the motions of the sun and the moon should have attracted attention earlier than those of the five planets known in antiquity, and that they should have been employed for measuring time. For a very long time the two great luminaries were supposed to move with uniform velocity. But the civic life of the Greek city-states made it important to regulate the calendar as accurately as possible, and this brought about a closer scrutiny of the motion of the sun. That this motion throughout the year is not uniform was first pointed out by Meton and Euktemon, about the year 433 B.C., when they discovered that the four seasons, that is the four intervals between the solstices and the equinoxes, were not quite of equal length. The corresponding discovery of the inequality of the moon's motion was not made till the middle of the fourth century B.C., as it was chiefly the exact moment of the appearance of the New Moon which was of interest for chronological purposes.

Even though the planets were probably not followed as carefully as the sun and the moon, it must have been noticed long before the age of Plato that the motions of the planets are subject to very conspicuous irregularities. The planet Mars, for instance, after having been invisible in the neighbourhood of the sun for some time, appears in the east before sun-rise. It is next seen to move through the constellations, increasing its distance from the sun, until it is exactly opposite the sun and passes the meridian at midnight. But before this happens, the planet gradually moves more slowly, becomes stationary, moves towards the west for a while (during which time it passes the point opposite the sun), stops again, and then resumes its ordinary movement towards the

east. How could this irregularity (which we now know to be caused by the earth's motion) be explained without giving up what seemed to be an indispensable assumption, that the planets could only move in circular orbits?

The first attempt to form a mathematical theory of planetary motions was made by Eudoxus, to whose distinguished mathematical work we have already alluded. To the assumption of circular motion he added another, that every planet was connected with a number of spheres, and that all these spheres were situated one inside the other and all concentric to the earth. Every planet (including the sun and moon) was supposed to be situated on the equator of a sphere, which revolves with uniform velocity round its two poles. In order to explain the stations and arcs of retrogression of the planets, as well as their motion in latitude, Eudoxus assumed that the poles of a planetary sphere are not immovable, but are carried by a larger sphere, concentric with the first one, which rotates with a different speed round two poles different from those of the first one. As this was not sufficient to represent the phenomena, Eudoxus placed the poles of the second sphere on a third, concentric to and larger than the two first ones, and rotating round separate poles with a speed peculiar to itself. For the sun and moon these three spheres were sufficient, but each of the five planets required a fourth sphere.

While all other ancient cosmical systems (apart from those which accept the rotation of the earth) account for the diurnal apparent motion of sun, moon, and planets across the sky by assuming that the sphere of the fixed stars during its daily revolution drags all the other spheres along with it, the system of Eudoxus provides a separate machinery for each planet for this purpose. Thus the motion of the moon was produced by three

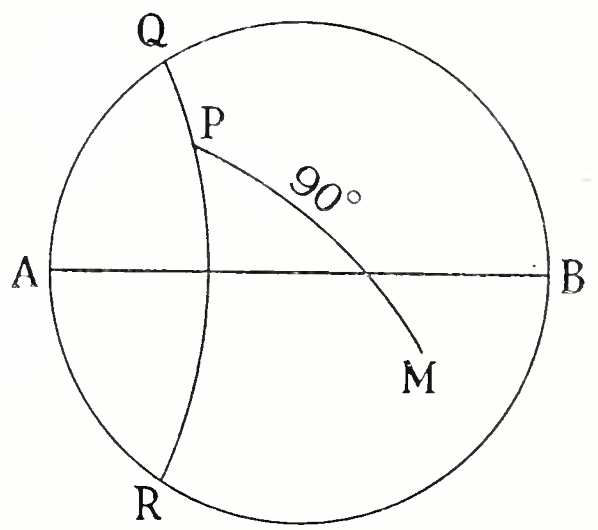
spheres; the first and outermost of these rotated from east to west in twenty-four hours like the fixed stars; the second sphere turned slowly in the same direction as the first one, round the axis of the zodiac. This sphere accounts for the retrograde motion (east to west) of the nodes of the lunar orbit (the points of intersection of the solar and lunar orbits) in $18\frac{1}{2}$ years. The third or innermost sphere turned from west to east round an axis inclined to the axis of the zodiac at an angle equal to the highest latitude reached by the moon (5°), producing the monthly motion of the moon round the heavens, as the moon was attached to a point in what we may call the equator of the third sphere.[1] That the motion of the lunar nodes was known at the time of Eudoxus is thus proved, while he apparently was not aware of the fact that the moon's motion in longitude is not uniform.

Similarly, in the case of the sun, there were three spheres, of which the outermost had the same daily motion as the sphere of the fixed stars. The second sphere has a very slow motion along the zodiac from west to east, while the third sphere turns in a year in the same direction round an axis inclined at a very small angle to that of the zodiac. The sun is here supposed to describe in a year, not the zodiacal circle (the ecliptic) itself, but a circle inclined at a very small angle to it, the nodes of which are supposed to have a very slow direct motion (W. to E.) instead of the retrograde motion of the lunar nodes. This is an altogether imaginary phenomenon, which was refuted by Hipparchus but was

[1] Simplicius, who has handed down to us an account of the system of Eudoxus (the latter's writings being lost), has by a slip interchanged the motions of the second and third lunar and solar spheres. This slip (first pointed out by Ideler) has been corrected above.

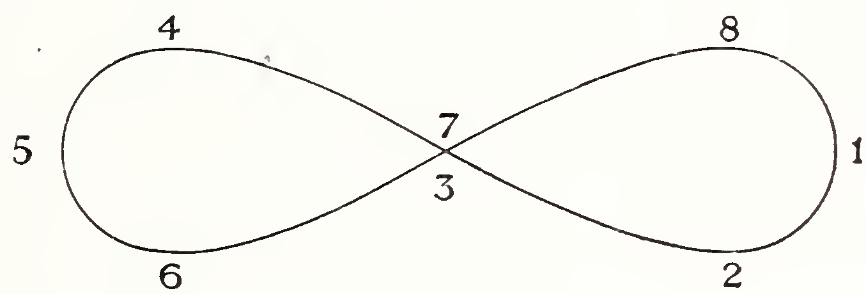
all the same accepted by Pliny and other much later compilers. It would have been better if Eudoxus had ignored it and had accounted for the variable orbital velocity of the sun, which, as we have seen, had been discovered 60 or 70 years earlier.

But the task which Eudoxus had set himself became vastly more difficult when he took up the theories of the five planets. Of the four spheres given to each of them the first and outermost produced the daily rotation of the planet round the earth in twenty-four hours; the second



produced the motion along the zodiac in a period which for the three outer planets was respectively equal to their sidereal periods of revolution, while it for Mercury and Venus was equal to a year. To represent the motion in latitude (in reality caused by the orbits of the planets being inclined to that of the earth), and also the irregular motion depending on the elongation from the sun, a third and fourth sphere were introduced for each planet. The third sphere had its poles situated at two opposite points of the zodiac (on the second sphere) and rotated round them in a period equal to the synodic period of the planet, that is the interval between two successive oppositions or conjunctions with the sun. These poles were different for the different planets, but

Mercury and Venus had the same poles. In the figure A and B are the poles of the third sphere, while P is one of the poles of the fourth. During the rotation of the third sphere P describes the circle QPR, while the fourth sphere in the same period, but in the opposite direction, completes a rotation round P and its other pole (not shown in the figure). The planet is at M in the equator of the fourth sphere, so that $PM = 90°$. If we leave the motion of the first or daily sphere altogether out of consideration and for the present also neglect that of the second sphere, the path described by M, projected on the plane of the circle $AQBR$, is found to be a curve



called by Eudoxus a hippopede, nowadays known as a lemniscate or figure of eight. The longitudinal axis of the curve lies along the zodiac, and its length is equal to the diameter of the circle described by P, the pole of the sphere which carries the planet. The double point is 90° from the two poles of rotation of the third sphere, A and B, and the planet passes over the arcs 1–2, 2–3, 3–4, 4–5, &c., in equal times. But the axis AB revolves round the zodiac in the sidereal period of the planet, carrying with it the lemniscate with uniform velocity. The combination of this motion with that of the planet on the lemniscate produces the apparent motion of the planet through the constellations. The period of the motion on the lemniscate is that of the synodical revolution, and during one half of this period the motion of the planet along the ecliptic becomes accelerated, and during the other half it becomes retarded, when the two

motions are in opposite directions. When on an arc of the lemniscate the backward oscillation is quicker than the simultaneous forward motion of the lemniscate itself, then the planet will for a time have a retrograde motion, before and after which it is stationary for a short time, when the two motions just balance each other. The greatest acceleration and the greatest retardation occur when the planet passes through the double point of the lemniscate. The motions must therefore be so combined that the planet passes through this point with a forward motion at the time of superior conjunction with the sun (when it is behind the sun as seen from the earth), where the apparent velocity of the planet is greatest. But the planet must pass through the double point in the retrograde direction at the time of opposition or inferior conjunction, when the planet appears to have the most rapid retrograde motion. This combination of motions will, of course, also produce a certain amount of motion in latitude depending on the breadth of the lemniscate.

The question how far this theory could be made to agree with the actually observed motions of the planets has been thoroughly examined by Schiaparelli in a memoir published in 1875. To be able to test the theory we require to know the values adopted by Eudoxus of the sidereal and synodic periods, and the distance between the poles of the third and fourth spheres, by Schiaparelli called the inclination. The value of the latter is not given anywhere, but the periods are given by Simplicius in round numbers, fairly correct with the exception of the synodic period of Mars, which he gives as 260 days, whereas it really is 780 days. The problem is now, with these values, to find a value of the inclination of each planet which will produce an arc of retrograde motion equal to the actually observed one, without making half

the breadth of the lemniscate, that is the greatest latitude of the planet, too unreasonably great. Schiaparelli found that this was possible in the cases of Saturn, Jupiter, and Mercury, so that the theory agreed sufficiently well with observation. But the theory was unsatisfactory as regards Venus, and it broke down completely when dealing with the motion of Mars, whether we put the synodic period equal to 260 days or to 780 days. It is however probable that Eudoxus had not at his command a sufficient series of observations, and only knew the main facts about the stationary points and retrogressions of the outer planets; and that these might be represented by some combination of concentric spheres had been proved by Eudoxus.

Some of the pupils of Eudoxus must have compared the movements resulting from the theory with those actually taking place in the heavens, since we find Kalippus of Kyzikus engaged in improving the system some thirty years after its first publication. He left the theories of Saturn and Jupiter untouched, but added a fifth sphere to each of the theories of Mars, Venus, and Mercury. Schiaparelli has shown that it was possible in this way to produce retrograde motion of sufficiently correct extent without making the breadth of the lemniscate and thereby the maximum latitude too excessive.[1] In the solar theory Kalippus introduced two new spheres to account for the unequal motion of the sun which had been discovered by Meton and Euktemon about a hundred years earlier. A lemniscate 4° in length and 2′ in breadth gives in fact the necessary maximum inequality of 2°. Similarly the number of lunar spheres was increased by two, which can only have been done in order to account for the inequality caused by the moon's motion in an

[1] For particulars see the writer's *History of the Planetary Systems*, Cambridge, 1906, pp. 104–7.

eccentric orbit; and Schiaparelli has shown that a hippopede 12° in length (the mean inequality is 6°) would only be twice 9′ in breadth, so that the improved theory of the moon was quite as good as any of the other planetary theories, as long as the evection or second lunar inequality had not been discovered.

While the system of concentric spheres was thus made more perfect by Kalippus, so that it could better 'save the phenomena' (i.e. account for the observed facts), it was fully accepted by his great contemporary, Aristotle (384–322). According to him, the universe is spherical, because the sphere is the most perfect body, and as the quickest motion is the most perfect, the outermost sphere (that of the fixed stars) is the most perfect sphere of all and is the seat of unchangeable order. It is under the immediate influence of the primary divine cause of motion, which from the circumference extends its power to the centre. In his work on Metaphysics Aristotle gives a short account of the system of Eudoxus and Kalippus. To him the spheres are not merely representatives of mathematical formulae, but physically existing parts of a vast machinery by which the celestial bodies are kept in motion. He is therefore obliged to introduce a number of extra spheres to prevent the motion of the outer spheres from being transmitted to the inner ones. Notwithstanding the great authority of Aristotle, the modified system of concentric spheres could, however, not hold its own among people who had a more detailed knowledge of the motions of the planets. But his ideas about the immutability of all bodies in the 'aethereal region' and his theory that comets originated in the upper parts of the atmosphere continued to prevail for nearly two thousand years.

The great difficulty in accepting the system of concentric spheres was that according to it every planet must

always be at the same distance from the earth. But how could that possibly be the case, when every planet was seen to vary very considerably in brightness? Mars, Jupiter, and Saturn were always brightest when opposite the sun; did that not indicate that they were at that time much nearer to us than when they were nearer the sun and much fainter? Similarly Venus and Mercury attained their greatest brightness at a certain angular distance from the sun. How could they be attached to a sphere, in the centre of which the earth was situated?

It is therefore not to be wondered at that other ways were sought of 'saving the phenomena', and this was already done by a contemporary of Aristotle, Herakleides of Pontus. His mind must have been singularly free from preconceived notions, since he accepted the doctrine held by some of the later Pythagoreans, that the earth turns on its axis once in twenty-four hours from west to east, thereby producing the apparent rotation of the heavens in the opposite direction. And Herakleides went even farther. There had been considerable difference of opinion among philosophers as to whether Mercury and Venus were nearer to us than the sun or farther off. It almost looked, judging by their changes of brightness, as if these two planets were sometimes on the near side of the sun and sometimes beyond the sun. This, in connexion with the fact that they are never seen at any great distance from the sun, made Herakleides realize that Mercury and Venus move round the sun and not round the earth. Unfortunately all his writings are lost, so that all we know of his doctrines is derived from the allusions of much later writers. We have therefore no evidence as to whether Herakleides took another step forward and suggested that the other three planets also travelled round the sun. A certain passage in a lost

book by Geminus (about 80 B.C.) quoted by the commentator Simplicius (about A.D. 500) has been interpreted by Schiaparelli as hinting that Herakleides even let the earth go round the sun. But not only is the passage in question strongly suspected of being corrupt, it is also contradicted by positive statements that Herakleides placed the earth in the middle and let it move 'not progressively but in a turning manner'.

But about fifty years later the hypothesis of the earth's motion round the sun was indubitably advanced by Aristarchus of Samos, who flourished about 280 B.C. In his case we are not dependent on the testimony of uncritical compilers; our authorities are Archimedes and Plutarch. The former tells us that Aristarchus 'published the hypothesis' that the earth is carried round the sun in a circle, and that the sphere of the fixed stars is of such a size that this motion does not produce apparent displacements among the stars in the course of a year. Plutarch, in his little book 'On the face in the disc of the moon', says that Aristarchus 'in order to save the phenomena supposed that the heavens stand still and the earth moves in an oblique circle at the same time as it turns round its axis'. In another of his writings Plutarch mentions that Aristarchus and Seleukus (a Babylonian geographer of the second century B.C.) held that the earth rotates, the former supposing it only, but the latter affirming it as true.

But what can have made Aristarchus think that the earth travels round the sun, and why did nobody else take up this fine idea, which had to lie dormant for eighteen hundred years?

Simplicius, after alluding to the great brightness of Mars when in opposition to the sun and to the changes of the apparent diameter of the moon, which made the system of concentric spheres untenable, says that as-

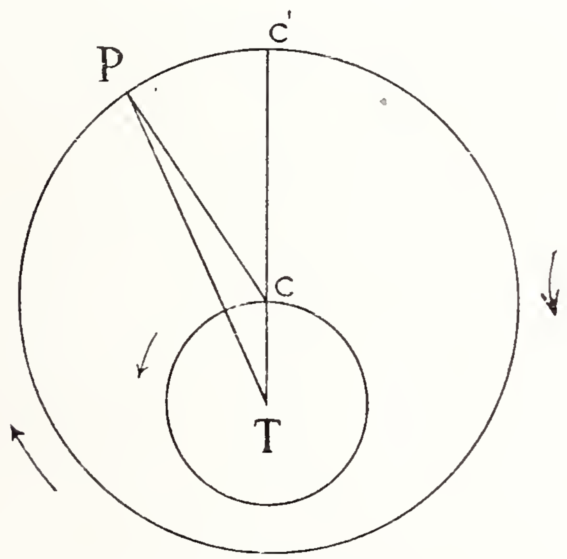
tronomers therefore introduced the hypothesis of eccentric circles and epicycles, if indeed the hypothesis of eccentrics was not already invented by the Pythagoreans, as stated by Nikomachus. This late writer's testimony is not worth much as regards the origin of the system of movable eccentrics; but that the latter was invented before the epicyclic theory is very probable indeed, and it is easy to see how the statement of Simplicius indicates the manner in which the way was prepared for the hypothesis of Aristarchus. To the Greek mind a heavenly body could not possibly move in any other curve than a circle. And as Mars was evidently nearest to us when in opposition, it followed that Mars must move on a circle which was eccentric to the earth, and furthermore that the centre of this circle lay somewhere on the straight line through the earth and the sun. Obviously this was not a fixed line, but one which turned round one of its extremities; consequently the centre of the orbit of Mars described a circle round the earth in a year, and everything would be explained by assuming that Mars moved round the eccentric circle from east to west in a period equal to its synodic revolution, that is, the interval between two successive oppositions (two years and fifty days). Jupiter and Saturn moved similarly on movable eccentrics. We cannot doubt that this system was known to Aristarchus. He must also have been acquainted with the hypothesis of Herakleides, that the centres of the orbits of Mercury and Venus lay in the sun. What then could be simpler than to assume that the centres of the orbits of the three outer planets not only lay somewhere on a line passing through the sun, but coincided with the sun? And having got so far, Aristarchus must have been struck by the fact that the phenomena would be precisely the same if he took one step farther, and instead of letting the sun, centre

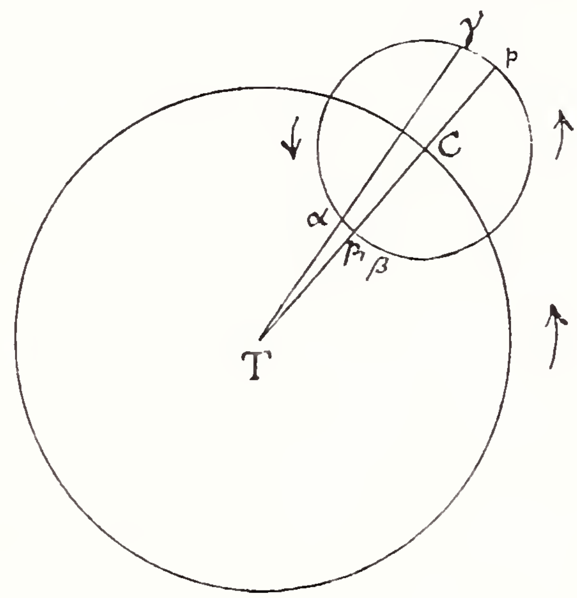
of all the planetary orbits, go round the earth, let the earth go round the sun, leaving everything else unaltered.

This must have been the way in which Aristarchus was led to his brilliant hypothesis. But why did nobody accept it? The few and scanty references to it by classical authors prove that it can never have been favourably received. We learn from Plutarch that Kleanthes the Stoic 'held that Aristarchus of Samos ought to be accused of impiety for moving the hearth of the world'; but prejudice of that kind can hardly have prevented the new hypothesis from being a success. But the Greece of the third century B.C. was very different from the aggregate of small city-states to which the poets and philosophers had addressed their works during the preceding two hundred and fifty years. Philosophical speculation had flourished there, and had been thought sufficient to solve the problems of the universe. But now the conquests of Alexander the Great had resulted in the foundation of large states, imbued with Hellenic culture and yet not severed from their own ancient civilization. A wider outlook ensued, and it was realized that only if based on accurately observed facts could scientific theory have a chance of succeeding. At the newly founded Museum of Alexandria observations began to be made, and it cannot long have escaped attention that just as the sun's apparent motion was not uniform (a fact perhaps neglected by Aristarchus), so also were the motions of the planets subject to inequalities. These were less conspicuous than those depending on the planet's distance from the sun, which the hypothesis of Aristarchus accounted for so well, but they could not be explained merely by assuming that the earth went round the sun. Thus the beautifully simple idea of Aristarchus fell to the ground.

The aim of mathematicians by degrees became to find

combinations of circular motion which would represent more or less closely the observed place of a planet at any time and give the means of finding this place by computation beforehand, without insisting on the actual physical truth of the system. In the course of nearly four hundred years the theory of planetary motions, which eventually became known as the Ptolemaic system, was developed, so far as we know, solely by Apollonius (230 B.C.), Hipparchus (130 B.C.) and Ptolemy (A.D. 140). Apollonius does not seem to have left any



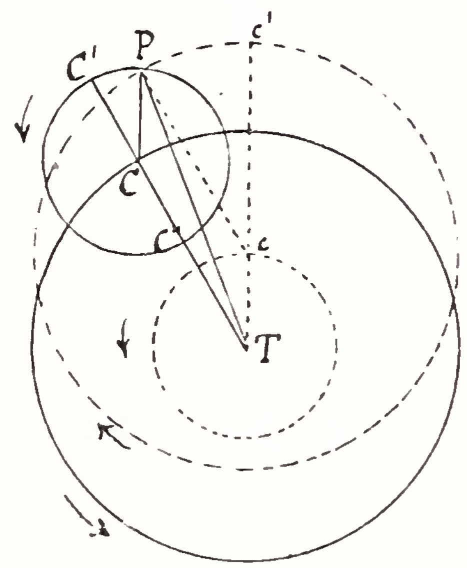


writings on astronomy; most of the writings of Hipparchus are lost, and Ptolemy in his great work on astronomy gives very little historical information about his predecessors. We therefore know very little about the gradual development of the Ptolemaic System. Ptolemy however describes at some length the two ways in which the motions of the three outer planets could be represented. We have already given a short account of the earlier of the two systems, that of movable eccentrics. In the first figure the larger circle is the orbit of a planet *P*, which travels round it in the synodic period from east to west, while the centre *C* in a year describes the smaller circle round *T*, the earth, from west to east. But this

system was not applicable to Mercury and Venus, and it did not illustrate the stationary points and retrograde motions as clearly as the system of epicycles did. The latter therefore soon drove it from the field altogether. In the second figure T is the earth, round which the point C performs a revolution in the period in which the planet travels round the heavens, for Saturn $29\frac{1}{2}$ years, for Jupiter nearly 12 years, for Mars 687 days. For Venus and Mercury the period is a sidereal year (the line TC always pointing to the sun), and this is also the period in which one of the three outer planets moves round the epicycle (the smaller circle) in the same direction from west to east. For the two inner planets the revolution on the epicycle takes place in the synodic period. The apparent motion of the planet as seen from T is therefore the resultant of two motions. When the planet reaches the point a, determined by $\frac{1}{2}a\gamma$ being to Ta in the ratio of the two linear velocities, the two angular velocities seen from T will for a short time be equal and opposite, so that the planet is stationary. After that the motion becomes retrograde as seen from T. This lasts until the planet reaches β, after which the planet again becomes stationary for a little while and then resumes its ordinary direct motion. It is evidently possible to fix the ratio of the radii of the two circles so that the observed length of the retrograde arc corresponds exactly to that given by the theory. The line TC always points towards the sun, and the planet is in opposition to the sun when it is at p_1 or nearest to the earth, and in conjunction with the sun when at p. It is also possible by means of an epicycle to represent the motion of a body which like the sun and moon moves with a somewhat variable velocity without ever becoming stationary or retrograde. In this case the motion on the epicycle has to be in the opposite direction to that of the motion on the larger

circle, or deferent as it was later on called, but in the same period.

That the result is the same whether we employ the movable eccentric or the concentric deferent with an epicycle to account for the motion of one of the outer planets is shown in the figure. The dotted circles represent the former theory, the others the deferent and epicycle, and it is necessary to make the radii *cP* and *TC* equal and also $Tc = CP$. But as already stated, the movable eccentric theory soon disappeared.



What we have here described in outline had most probably been reached before the time of Hipparchus. He was a native of Nicaea, but spent most of his time at Rhodes. He was able to make use of observations made at Alexandria in the previous 150 years, and by means of them he made his great discovery of the Precession of the Equinoxes, whereby the longitudes of all stars increase at the rate of 50″ per annum. He was also himself an indefatigable observer, and prepared a catalogue of the positions of about 850 stars, which unfortunately has been lost. But he had also at his disposal observations of eclipses made in Babylonia centuries before the foundation of the Museum of Alexandria, and this enabled him to determine the orbits of sun and moon

more accurately. In the case of the sun it was easy enough, since the unequal length of the four seasons was the only inequality to be accounted for; and this could be done either by a simple eccentric circle or by an epicycle. The same was the case with the moon, but matters were here somewhat more complicated, as the nodes (or points of intersection of the moon's orbit and the apparent orbit of the sun) travel from east to west right round the heavens in about $18\frac{1}{2}$ years, a fact which, as we have seen, had already been taken into account by Eudoxus. In addition to this the line of apsides (points of greatest and least distance of the moon) move round the heavens from west to east in nearly nine years, which was accounted for by making the motion on the deferent about 3° per revolution in excess of the motion on the epicycle. As his predecessors had only furnished him with observations of eclipses, Hipparchus could only produce a theory of the moon's motion which represented that motion at new and full moon sufficiently well. He noticed that observations of the moon about the time of first or last quarter sometimes did not agree with his theory, but he had to leave the investigation of this to his successors. Similarly in the case of the five planets, want of observations prevented him from making any advance.

The epicyclic system received its last development in the second century from Claudius Ptolemy, who embodied his predecessors' and his own work in a great book called the *Mathematical Syntaxis*. In addition to a catalogue of 1,025 stars, it discusses the motions of the sun, moon, and planets. In the theory of the moon he made very substantial improvements by discovering the second inequality, now known as the evection (dimly suspected by Hipparchus), and fixing its amount at $1° \, 19\frac{1}{2}'$, very near its true value. To allow for this the centre of the moon's epicycle had not only to move on an eccentric circle, but further complications had to be

introduced in the theory, which must be passed over here. Ptolemy had also to add a somewhat similar complication to the planetary theory of Apollonius to account for the apparent irregularity which we now know to be caused by a planet moving in an elliptic orbit with variable velocity. He introduced a 'punctum aequans', so situated on the line of apsides that the earth was midways between it and the centre of the deferent. The line from the equant to the centre of the epicycle moved so that it described equal angles in equal times. Even this was not enough for the planet Mercury, the theory of whose motion was still more complicated.

As a ready means of computing the movements of sun, moon, and planets, the Ptolemaic system is deserving of the highest praise. By its authors it was certainly not intended to represent the actually existing state of the heavenly bodies. For it could not possibly have escaped Hipparchus and Ptolemy that their theory of the moon involved excessive variations of the moon's distance, and thereby of its apparent diameter, which never happened in reality. Owing to the state of algebra at that time, geometry had to be pressed into the service of astronomy, just as Euclid had to adopt a geometrical representation when dealing with irrational quantities or the theory of proportion.

But the truth, that is the Copernican system, lay hidden all the time among the deferents and epicycles of the Greek mathematicians. We can reproduce Ptolemy's values of the ratio of the radii of epicycle and deferent from the semi-axis major of each planet expressed in units of that of the earth as shown in the following table:

	Semi-axis major (a)	$\frac{1}{a}$	*Ptolemy's ratio.*
Mercury .	0·387	—	0·371
Venus .	0·723	—	0·719
Mars . .	1·524	0·656	0·658
Jupiter .	5·203	0·192	0·192
Saturn .	9·539	0·105	0·108

But for more than fourteen hundred years the idea of Aristarchus remained dormant and unrecognized, and the Ptolemaic system was almost universally accepted. All the same, the system was totally at variance with Aristotelean Physics, the adherents of which objected strongly to the movements around points outside the centre of the world. Attempts had therefore been made even before the time of Ptolemy to reconcile the two systems. As long as the deferent was assumed to be concentric with the earth, the epicycle might be supposed to be the equator of a solid sphere, rolling between two solid concentric spheres. This idea, which is described by Theon of Smyrna (soon after A.D. 100), became insufficient as soon as the deferents became eccentric circles. In the *Syntaxis* Ptolemy ignores it, but in a later work, the *Hypotheses of the Planets*, or rather in the second book of it, he sets forth a development of the system described by Theon. The epicycle sphere now fits between two eccentric spherical surfaces (an inner and an outer one), near the common centre of which the earth is situated. This theory of the world, which its author made as elaborate in its way as the epicyclic system, was not a success. The Greek original is lost, but an Arabic translation of the second book of *Hypotheses* has been preserved and has some years ago become more accessible through a German translation. This and other systems of spheres seem to have appealed strongly to Eastern minds, and throughout the Middle Ages various combinations of spheres were proposed by some Mohammedan philosophers, who could not feel satisfied with the Ptolemaic system of circles. This was particularly the case in Spain, and was connected with the rise of Aristotelean philosophy in that country. From Spain the fight between the circles and the spheres spread to Paris and to Oxford, and it was not until about the

year 1300 that the system of epicycles was finally victorious.

Thus the *Syntaxis* of Ptolemy remains the acme of Greek astronomy. Whatever may be said against the Ptolemaic system of the world as being apparently complicated and difficult to believe in, it must be conceded that from a mathematical point of view it was perfect. It gave the means of computing tables of the movements of the planets, which supplied positions not differing too much from those observed with the imperfect instruments then available, except after long periods of time. It might even have been further developed, when observations had shown the necessity for doing so, as the system is quite analogous to a development in a series of sines or cosines of multiples of certain angles. It was worthy of the great minds by whom it was started, in the days when Greek social development and intellectual life were at their best; and of those who completed it, when Greece and the Hellenized countries had become parts of an Empire embracing most of the known world and giving its citizens opportunities for extended activities far beyond what the small Greek city-states had been able to offer.

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V

THE DARK AGES AND THE DAWN

CHARLES SINGER

§ 1. *The Limits of the Middle Ages of Science*

THE task that falls to the writer on the Middle Ages in such a volume as this might be deemed far from attractive. The epoch, by general admission, presents us with a set-back in the development of scientific ideas. During the period between the fall of the Empire and the revolution in physics carried through by Galileo in the seventeenth century, the conceptions as to the nature of the world in which they lived that prevailed among educated men was not conducive to the first-hand study of nature. It is because these views were finally shattered by Galileo and his successors that many of the authors whose works we shall have to discuss may seem insignificant. Yet some of these men, who are now well-nigh forgotten, have had their share in determining the current of human thought and with it the course of human destiny. The test of importance that we must apply is not our assent to their opinions but the influence their work has had on the period we are considering. We shall remember too that the period has the intense interest of presenting us with the *beginning* of something, the birth—or rebirth—of the scientific idea.

We cannot, then, pass over in silence the millennium that intervenes between antiquity and modernity. There is a continuity in the history of the human intellect, for civilization is a unique phenomenon and there is no real evidence that it has occurred more than once

in the world's history. To understand our own version of civilization we must trace it back to its origin, and this we can do only *through* the Middle Ages. It is beside the point to urge that the Middle Ages contributed little to the actual sum of knowledge of the external world. What we want to know is *why* they contributed so little, and *how*, contributing so little, they yet succeeded in passing on to our time the basic ideas from which science has grown.

These Middle Ages, after all, were not a thousand years of cataclysm. They represent doubtless a deterioration of the human mind, but the nature and causes of that deterioration are themselves the subject of intense scientific interest. The Middle Ages can no more be disregarded in considering the general course of science than can a degenerate or parasitic series of plants or animals be passed over when considering the larger group to which they belong and from which they have sprung. The very degeneracy of such a series has an interest of its own, and often, by helping us to exclude accidental elements, enables us to detect essential traits of the group which we might otherwise overlook.

We may begin our task with some attempt to delimit the period with which we are concerned. Without attempting to define science, we may describe it as the process of making knowledge. Being a *process* it must also involve the idea of progress or at least of movement. The world of science is a dynamic world with its own stores of ever-acting energy. The world of the mediaeval thinker was a static one, a world in which such forces as were acting were impressed from without. When and how was this static element introduced?

We may first consider the *terminus a quo* of the mediaeval attitude toward the external world. The Middle Ages begin for science at that period when the ancients ceased

to make knowledge. Now, ancient science can be clearly traced as an active process up to the end of the second century of the Christian era. Galen, one of the very greatest and most creative biologists of all time, died A.D. 201. Ptolemy, one of the greatest of the cosmographers, was his older contemporary. After Galen and Ptolemy, Greek science flags and scientific inspiration dwindles.

Mathematics holds out the longest, but with the mathematician Theon of Alexandria, who died about 400, we part altogether with the impulse of the science of antiquity. Stoicism and Neoplatonism too, the chief systems of thought of the late Empire, are dying and are giving place to that great philosophical and religious movement, the repercussion of which is felt right through the Middle Ages and down to our own time. The standpoint of its great protagonists, Tertullian (155–222), Lactantius (260–340), and, above all, St. Jerome (340–420) and St. Augustine (354–430), is outside the department with which we have here to deal, but it was assuredly not conducive to the exact study and record of phenomena. We may fix the end of Antiquity and the beginning of the Middle Ages for science at the end of the fourth or the beginning of the fifth century.

The *terminus ad quem* of mediaeval science is, perhaps, less easy to determine. Mediaevalization, in our view, was a slow process under the action of which the human mind, failing to increase the stock of phenomenal knowledge, sank slowly into an increasing ineptitude. At a certain point the nadir of mental deterioration was reached and intellectual competence tended again upward. The time of lowest degradation of the human intellect varied according to the state of civilization in different parts of Europe. It was probably most general about the tenth century. After this may be

discerned a slow ascent. Later, in the thirteenth and fourteenth centuries, we encounter considerable extension of natural knowledge. There is still, however, no wide-spread acceptance of the ancient view that had been voiced by the philosopher Seneca (3 B.C.–A.D. 65) that knowledge may be indefinitely extended. That view appears to be an essential element in any effective doctrine of progress. In the scholastic period, however, there do at last appear a very few forward-looking minds such as that of Roger Bacon (1214–1294), but they are as yet very rare and exceptional. When we reach the fifteenth century and the full influence of humanism we encounter a larger number of forward-looking thinkers, but they are still isolated. Not until the sixteenth century is there any effort, at once organized and conscious, to translate into action this new-born hope in the future. It is only in the early years of the seventeenth century that the hope obtains formal philosophical expression once more with Francis Bacon (1561–1626) and René Descartes (1596–1650). By that time, however, not only are the Middle Ages past but they are so much forgotten that the reading public needs skilled interpreters to explain the mediaeval point of view.

If we have to name a year for the end-point of mediaeval science we would select 1543. In that year appeared two fundamental modern works based on the experimental method, the *De fabrica corporis humani* of the Belgian Andreas Vesalius (1514–1564) and the *De revolutionibus orbium caelestium* of the Pole Nicholas Copernicus (1473–1543). It is true that for generations before 1543 there was a dawning consciousness of the inadequacy of the mediaeval cosmic system. That discontent, however, was vague and ill-expressed, and of the nature rather of mental discomfort than of intellectual revolt. It is also true that for some generations after the time of

Vesalius and Copernicus the characteristic doctrines of the science of the Middle Ages were almost universally taught in the schools. Such doctrines, too, were still diffused by literature, and are, for instance, displayed in the writings of Shakespeare. But the ideas on which the works of Vesalius and Copernicus had been based gain, from this time onward, an ever wider hearing. The year 1543 saw for the first time two published authoritative works that formally rejected the old views. These works, though produced by men who had steeped themselves in the old system, yet provided a new standpoint. For science, then, 1543 is the natural *terminus ad quem* of the Middle Ages.

Now, since the human mind turned on its upward course after the tenth century, and since the process was accelerated during the great scholastic period of the thirteenth century and again at the Revival of Learning of the fourteenth and fifteenth centuries, it may be asked, why should we not choose one or other of these dates as the end-point of the scientific Middle Ages? The thirteenth century, the epoch of consolidation of Catholic philosophy, has been selected as one of exceptional enlightenment, and has been specially exalted by those who lay great emphasis on the continuing rôle of the Church in the development of the intellectual system of our modern world. There are, therefore, some who would place the division in the thirteenth rather than in the sixteenth century. There are yet others, biassed perhaps by the literary training of the classics, who would place the cleavage about the year 1400. They would make the Revival of Learning, and especially of Greek letters, the basis of the differentiation between mediaeval and modern. Yet to make the great division at any such date as 1000, 1200, or 1400 would be an error, because, with very few exceptions, the point of view of the eleventh-century

encyclopaedist, of the thirteenth-century scholastic, and of the fifteenth-century scholar was formally and essentially an effort to return to the past. It was the literature and language of antiquity, the antiquity of the fathers, of the philosophers, or of the poets, that these men sought more or less vainly to revive.

In an encyclopaedia of the eleventh century nothing can be found that is not derived from patristic sources.

The great Catholic scholastics of the thirteenth century believed that they were reconstructing the philosophy of Aristotle. Few first-hand students of that great man of science will now be found to agree with the interpretation supplied by them. It is true that, despite the errors of philosophical interpretation, scientific elements are not wholly wanting in scholastic writings. Yet in that age the infinity of the knowable universe was passionately denied, originality of view was furtively hidden under the cloak of authority, and knowledge—so the knowers claimed—was always based on the wisdom of antiquity. Imitation rather than origination was the characteristic mental attitude also of the most enthusiastic scholars of the fifteenth century.

The Revival of Learning also, even the process by which the ancient texts were recovered, though it may rightly be regarded as containing scientific elements, had for its motive the imitation of the past by the present, rather than the modern archaeological aim of the mental reconstruction of the past with the object of understanding the present. The ablest writers of the time sought to become the 'apes of Cicero'. What is true of the literary studies of the Renaissance is just as true of the scientific studies of the period. The rescue of the Greek texts, though it enlarged the mental horizon, chained men's minds more closely than ever to the past. Even the revolt against the 'Arabists', led with such enthusiasm by the

classical scholars, had for its object a yet closer return to antiquity.

There is a point, however, at which those interested in phenomena—the physicists, and especially the physicians—show a general willingness to turn their gaze from the past and toward the future. We may at least say of the two great works that appeared in 1543 that they present a new thing in that their authors are looking to the future for the development and vindication of their views.

The work of the aged Copernicus, though not published till 1543, had been prepared many years before. It is therefore much the more conservative of the two, and still bears marks of the Middle Ages on every page. Vesalius, on the other hand, when he published his magnificently printed and illustrated *Fabrica* was a vigorous young man of but twenty-eight. Only four years earlier he had produced a treatise which, while rejecting the anatomical views of the Arabists, had expressed full faith in the complete reliability of Galen. His conversion had been rapid, and now he parts definitely with the Middle Ages. As an anatomical observer he has become independent. His physiological theory, however, is still based on Galen just as surely as the circular orbits ascribed by Copernicus to the planets are derived from Aristotle.

With Copernicus and Vesalius, however, organized and systematic *observation* had found her place. Fabricius ab Aquapendente (1537–1619) in Anatomy and Tycho Brahe (1546–1601) in Astronomy did but practise a method which their two great predecessors had formally initiated. But for the process of free generalization on such observation and for the effective wielding of the new weapon of *experiment* the world had still to wait for the generation of Galileo (1564–1642), Kepler (1571–1630), and Harvey (1576–1657).

§ 2. *The Dark Age*

Thus for effective purposes we may place the limits of the mediaeval attitude towards nature between the years 400 and 1543, with a debatable period of another half century up to 1600. This vast stretch of time is divided by an event of the highest importance for the history of the human intellect. Between the beginning of the tenth and the end of the twelfth century there was a remarkable outburst of intellectual activity in Western Islam. This movement reacted with great effect on Latin Europe, and especially on its views of nature, by means of works which gradually reached Christendom in translations from the Arabic. In the light of this great intellectual event we may divide our vast mediaeval period into three parts, an earlier *Dark Age*, an intermediate *Age of Arabian Influence*, and a later *Scholastic Age*. The *Age of Arabian Influence* may itself be conveniently sub-divided into an earlier period of *Arabian Infiltration* and a later one of *Arabian Translation*. During all these periods the general beliefs as to the nature of the external world hardly change, but the difference in presentment of the material is such that the mediaevalist need seldom be in doubt into which category to place any document from these centuries treating of a scientific topic.

The task of the first mediaeval period was the conveyance of the remains of the ancient wisdom to later ages. During the closing centuries of the classical decline, the literature that was to be conveyed had been delimited and translated into Latin, the only language common to the learned West. We may briefly discuss this classical heritage.

The work of Plato that is least attractive and most obscure to the modern mind fitted in well with the prevalent views of the Neoplatonists. The commentary on

the *Timaeus*, prepared by Chalcidius in the third century from a translation by Apuleius in the second, presents the basis of views held throughout the entire Middle Ages on the nature of the universe and of man. Thus the *Timaeus* became one of the most influential of all the works of antiquity, and especially it carried the central dogma of mediaeval science, the doctrine of the macrocosm and microcosm.

Of Aristotle there survived only the *Categories* and the *De interpretatione*, translated in the sixth century by Boethius (480–524). A Greek introduction to the *Categories* had been prepared by Porphyry in the second century, and this also was rendered into Latin by Boethius. Thus the only Aristotelian writings known to the Dark Age of science were the logical works, and these determined the main extra-theological interest for many centuries. It is a world-misfortune that Boethius did not see his way to prepare versions of those works of the Peripatetic school that display powers of observation. Had a translation of Aristotle's *Historia animalium* or *De generatione animalium* survived, or had a Latin version of the works of Theophrastus on plants reached the earlier Middle Ages, the whole mental history of the race might have been different. Boethius repaired the omission, to some small extent, by handing on certain mathematical treatises of his own compilation, the *De institutione arithmetica*, the *De institutione musica*, and the (doubtful) *Geometrica*. These works preserved throughout the darkest centuries some fragment of mathematical knowledge. Thanks to them we can at least say that during the long degradation of the human intellect, mathematics, the science last to sink with the fall of the Greek intellect, was not dragged down quite so low as the other departments of knowledge. The main gift of Boethius to the world, his *De consolatione philo-*

sophiae, which preserved some classical taste and feeling, lies outside our field.

A somewhat similar service to that of Boethius was rendered by Macrobius (395–423) and by Martianus Capella (*c.* 500). The latter, especially in his *Satyricon*, provided the Dark Age with a complete encyclopaedia. The work is divided into nine books. The first two contain an allegory, in heavy and clumsy style, of the marriage of the god Mercury to the nymph Philology. Of the last seven books of the work, each contains an account of one of the 'Liberal Arts', grammar, dialectic, rhetoric, geometry, arithmetic, astronomy, and music, a classification of studies that dates back to Varro (116–27 B.C.) and was retained throughout the Middle Ages. The section on Astronomy has a passage containing a heliocentric view of the universe, a view that had been familiar to certain earlier Greek astronomers. The cosmology of Capella, like that of Chalcidius, is Neoplatonic, as is also the work of Macrobius, whose commentary on the *Somnium Scipionis* of Cicero gave rise to some of the most prevalent cosmological conceptions of the first mediaeval period.

In addition to the little cosmography, mathematics, and astronomy that could be gleaned from such writings as these, the Dark Age inherited a group of scientific and medical works from the period of classical decline. By far the most important was the *Natural History* of Pliny the elder (A.D. 23–79), which deeply influenced the early encyclopaedists. Somewhat akin to it are the *Quaestiones naturales* of the moralist Seneca (3 B.C.–A.D. 65), whose ethical attitude toward phenomena delighted many mediaeval writers by whom he was taken for a Christian.

Very curious and characteristic is a group of later pseudepigrapha bearing the names of Dioscorides, Hippocrates, and Apuleius. These works were probably all

prepared or at least translated between the fourth and sixth centuries. They provided much of the medical equipment of the Dark Age.

Such material, then, was the basis of the mediaeval scientific heritage. Traces of it are encountered in *De Institutionibus divinarum et humanarum literarum* of Cassiodorus (490–585), perhaps the earliest general writer whose works bear the authentic mediaeval stamp. The scientific heritage is, however, much more fully displayed in the *Origines* of Isidore of Seville, a late sixth-century work which formed a cyclopaedia of all the sciences in the form of an explanation of the terms proper to each. For many centuries Isidore was very widely read, and the series Isidore (560–636), Bede (673–735), Alcuin (735–804), Rabanus Maurus (776–856), who borrow from one another successively and all from Pliny, may be said to contain the natural knowledge of the Dark Age. These writers are summarized by the early eleventh-century English writer Byrhtferth (died *c.* 1020), whose copious commentary on Bede may be regarded as the final product of the nature-knowledge of the Dark Age. With this somewhat belated author we part company with the Dark Age and enter upon a new period, with new forces and new movements at work.

§ 3. *The Age of Arabian Infiltration*

The tenth century and those that follow bring us into relation with the wisdom of the East. In these centuries the relation of East and West with which we are nowadays familiar is reversed. In our time most Oriental peoples recognize the value of Western culture, and give it the sincerest form of flattery. The Oriental recognizes that with the Occident are science and learning, power and organization and public spirit. But the admitted

superiority of the West does not extend to the sphere of religion. The Oriental who nowadays gladly accepts the Occidental as his judge, his physician, or his teacher, wholly repudiates, and perhaps despises, his religion. In the Europe of the tenth, eleventh, and twelfth centuries it was far otherwise. The Westerner knew full well that Islam held the learning and science of antiquity. His proficiency in arms and administration had been more than sufficiently proved—the Occidental belief in them is enshrined in our Semitic words 'arsenal' and 'admiral'. There was a longing, too, for the intellectual treasures of the East, but the same fear and repugnance to its religion that the East now feels for Western religion. And the Western experienced obstacles in obtaining the desired Oriental learning analogous to those now encountered by the Eastern in the Occident.

The earliest definitely Oriental influence that we can discern as affecting ideas about nature is of the character of infiltration rather than direct translation. The literary first agents of this process appear to have been mainly Jews who had been under Saracen rule. Such influence can be traced in two works in the Hebrew language by Sabbatai ben Abraham ben Joel (913–982), better known as Donnolo, a Jew of Otranto who practised medicine at Rossano in Southern Italy. Donnolo learnt Arabic while a prisoner in Saracen hands; he was taught the language by a native of Bagdad, and, like Constantine the African in the next century, claimed to have studied 'the sciences of the Greeks, Arabs, Babylonians, and Indians'. He travelled in the Italian peninsula in search of learning, and must thus have spread some of his Arabic science. His most important work, known as the *Book of Creation,* is dated to the year 946. It is a mystical treatise of great historical and philological interest and involves a knowledge of astrology. It unquestionably draws on Arabic

sources, and sets forth fully the ancient doctrine encountered in the *Timaeus* of the macrocosm and microcosm or parallelism between the external world of nature and the internal world of man's body. This idea was very popular among the Arabian writers.

The earliest Latin document exhibiting Oriental influence is a treatise on astrology to which the name 'Alchandrus' (Alexander?) is attached. This work has come down to us in a manuscript written about 950 or a little later, probably in Southern France. The repeated use of Hebrew and Arabic equivalents for the names of constellations and planets, and the occasional use of Hebrew script, leave no doubt that it also is of Jewish origin.

The existence of these works enables us to understand the Oriental influence in the mathematical writings of the learned Pope Silvester II (Gerbert, d. 1003), who spent some years in Northern Spain, where Jews are known to have acted as intermediaries between Moslems and Christians. Gerbert was, perhaps, among the earliest to introduce the Arabic system of numbering, which slowly replaced the much clumsier Roman system, with its tiresome use of the abacus for simple mathematical processes. He is also believed to have instigated a translation from the Arabic of a work on the Astrolabe.

Hermann the Cripple (1013–1054) spent his life at the Benedictine abbey of Reichenau in Switzerland. He wrote certain mathematical and astrological works which were extensively used in the following century. Hermann was unable to read Arabic, and could not travel by reason of his infirmity. Yet his writings display much Oriental influence, which was almost certainly conveyed to him by wandering scholars of the type of Donnolo and 'Alchandrus'. Similar though somewhat belated evidence of the influence of what we have called the process of

Arabic infiltration is exhibited in the lapidary of Marbod of Anjou, Bishop of Rennes (1035–1123), and in the extremely widely read work on the medicinal use of herbs, probably composed by Odo of Meune, Abbot of Beauprai (Macer Floridus, d. 1161).

The Arabic learning thus beginning to trickle through to the West in a much corrupted form was, however, by no means an entirely native Saracen product; it was derived ultimately from Greek work. There was, indeed, yet one channel by which the original Greek wisdom might still reach Europe. Communication between the West and the Byzantine East was very little in evidence in the centuries with which we are now concerned, but a Greek tradition still lingered in certain Southern Italian centres, and especially in Sicily. South Italy and Sicily remained for centuries under the nominal suzerainty of Byzantium, and the dialects of the island bear traces to this very day of the Greek spoken there and in Calabria and Apulia until late mediaeval times. But the Saracens had begun their attacks on Sicily as early as the eighth century, and their rule did not cease until the Norman conquest of the eleventh century. The Semitic language of the Saracens left the same impress on the island as did their art and architecture, so that between the tenth and twelfth centuries Sicily is a source of both Greek and Arabic learning for Western Europe.

One seat of learning in the Southern Italian area felt especially early the influence of the Graeco-Arabic culture. Salerno, on the Gulf of Naples, had been a medical centre as far back as the ninth century. It is clear from surviving manuscripts that, even apart from the Greek language, some traces of ancient Greek medicine lingered in Latin translation widely diffused in Magna Graecia during the centuries that succeeded the downfall of the Western Empire. Such learning as remained was galvanized into

life by Saracenic energy and, with what we know of the carrying agents of Arabic culture, it is easy to understand the tradition that attributes the founding of the great medical school of Salerno to the co-operation of a Greek, an Arab, a Latin, and a Jew. From the latter part of the eleventh century Salernitan material is full of Semitic words, a few of which, such as the anatomical term 'nucha' and the names of some drugs, linger in medical nomenclature to this day.

§ 4. *Translation from the Arabic*

A very important agent of the Arabic revival was Constantine the African (d. 1087), a native of Carthage, who came to Italy about the middle of the eleventh century. He became a monk at Montecassino, and spent the rest of his life turning current Arabic medical and scientific works into Latin. His sources are mainly Jewish writers of North African origin. In his desire for self-exaltation Constantine often conceals the names of the authors from whom he borrows, or he gives them inaccurately. His knowledge of both the languages which he was treating was far from thorough, and his translations are wretched. But these versions were very influential, and they remained current in the West long after they had been replaced by the better workmanship of Toledo students of the type of Gerard of Cremona (1114–1187). It is interesting to note that one of Constantine's works is dedicated to Alphanus, Archbishop of Salerno (d. 1085), who was perhaps the first medical translator direct from the Greek.

The earliest Oriental influences that reached the West had thus been brought by foreign agents or carriers, but the desire for knowledge could not be satisfied thus. The movement that was soon to give rise to the univer-

sities was shaping itself, and the Western student was beginning to become more curious and more desirous of going to the well-springs of Eastern wisdom.

His main difficulty was one of language. Arabic was the language of Eastern science and letters, and its idiom was utterly different from the speech of the peoples of Europe. Moreover, its grammar had not yet been reduced to rule in any Latin work, nor could teachers be easily procured. Even in the thirteenth century we find that Roger Bacon, though he clearly perceived the importance of linguistic study and eagerly sought to unlock the literature of foreign tongues, had still not found the key. He had only time to commence laboriously the grammatical apparatus of the Greek and Hebrew languages. The only way to learn Arabic was to go to an Arabic-speaking country. Yet this was a dangerous and difficult adventure, involving hardship, secrecy, and perhaps abjuration of faith. Moreover, to learn the language at all adequately for rendering scientific treatises into Latin meant a stay of years, while the work of translation demanded also some understanding of the subject-matter to be translated. There is good evidence that an effective knowledge of this kind was very rarely attained by Westerns, and probably never until the later twelfth century.

At the period during which Western science began to draw from Moslem sources there were only two areas of contact of the two cultures: these were respectively Spain and 'the Sicilies'. The conditions in the two were somewhat similar. In the tenth century the Iberian peninsula was Moslem save for the small kingdoms of the French march, Leon, Navarre, and Aragon. Here the grip of Islam had soon relaxed, and this territory remained historically, religiously, racially, and linguistically a part of the Latin West. The Moslem South was ruled from Cordova, which

became increasingly Mohammedanized, but at the more northern Toledo the subject population, though speaking an Arabic patois, remained in the main Christian, though with a very large Jewish element. In 1085 Alphonso VI of Leon (Alphonso I of Castille), aided by the Cid, conquered Toledo, and there most of the work of transmission took place.

The schools of Southern Italy and Sicily were on the whole less influential, though their work of translation continued to a somewhat later date. They are, however, important in another respect, for from them went forth the first renderings of scientific works made direct from the Greek. These translations of scientific works direct from the Greek began to appear as early as the eleventh century, when Alphanus Archbishop of Salerno (d. 1085) produced a Latin version of a work by Nemesius (fourth century). Such translations increased in number and importance gradually and very slowly. A most interesting worker in Sicily was Burgundio of Pisa (d. 1194), who made translations both from the Arabic and the Greek.

It is evident that the process of translation from Arabic, especially in Spain, was frequently carried on by the intervention of Jewish students, and many of the translated works were themselves by Jews. The tenth, eleventh, and twelfth centuries, a time of low degradation of the Latin intellect, was the best period of Jewish learning in Spain. Arabic was the natural linguistic medium of these learned Jews. Among them were the Egyptian physician Isaac Israeli ben Solomon (d. *c.* 1000) called in the West Isaac Judaeus, Solomon ibn Gabirol (1021–1058?) of Saragossa who was disguised in scholastic writings as Avicebron, and Moses ben Maimon (1135–1204) of Cordova, more familiarly known as Maimonides. These three authors were among the more important and influential that were rendered into Latin from Arabic during the Middle Ages,

and their works form part of the Eastern heritage won by the translators during these centuries. All three deeply influenced Western scholasticism.

In the twelfth, thirteenth, and fourteenth centuries, when the tide had turned and Islam was in retreat, it was occasionally possible for a scholar with a gift for languages, such as Gerard of Cremona (1114–1187), to find a skilled native Christian teacher. But in the tenth or eleventh century Christian learning and Christian society in Spain were subject and depressed. Like many modern peoples similarly placed, these native Christians were attached with the more fanaticism to the religion which held them together and to the language of their Church. The student of an earlier time could find no effective Christian teacher of literary Arabic, while the very sciences which he sought to acquire were suspect as the mark of the infidel and the oppressor.

It thus comes about that there is some obscurity—much of it doubtless intentional—as to the circumstances under which the best translations from the Arabic were made. It is apparent, however, that these earlier versions were sometimes prepared by a group of three or more who would interpret one to the other. One would turn the Arabic text, sentence by sentence, into the vernacular or into Hebrew, another would then render it into Latin and perhaps a third would turn it into literary form. Naturally, in this process many words would be encountered that could not be rendered either into the vernacular or into the barbarous Latin of the time. Especial difficulty would be encountered with technical terms. The meaning of some of these might well be imperfectly known to the translators themselves. Such words were therefore often simply carried over, transliterated, in their Arabic or Hebrew form, and the early versions are full of Semitic expressions. The Latin mediaeval astronomical

and mathematical vocabularies especially abound in these Semitic words, many of which, such as 'azure', 'zero', 'zenith', 'cipher', 'azimuth', 'algebra', 'nadir', and names of stars, as 'Aldebaran' and 'Altair', are still in use. Most of the Latin medical literature of the Middle Ages, too, was of Arabian origin and contained a whole host of Semitic words which, however, were almost all displaced by equivalents of Greek origin during the sixteenth and seventeenth centuries.

The sort of translation which emerged from the process that we have described may well be imagined. When it is also remembered that to reach the Arabic from the original Greek the text had already passed through similar stages, usually with Syriac as an intermediary, it will be understood that the first scientific books that reached the West were often but travesties of the Greek originals from which they were ultimately derived.

Men who may be supposed to have worked in such a way as we have pictured are Adelard of Bath (*c.* 1100), who journeyed both to Spain and to Sicily, and published a compendium of Arabic science, and the wizard Michael Scot (1175 ?–1234 ?), who visited the court of Frederick II at Naples and produced versions or abridgements of the biological works of Aristotle. Such men, like Gerbert before them and Peter of Abano after them, were frequently accused of magical practices. More scientific in their methods and probably better equipped linguistically were Robert of Chester (*c.* 1144), who rendered the Koran into Latin and translated the valuable algebra of Al Khowarizmi (fl. 830) as well as works on alchemy and astronomy, and Alfred the Englishman (*c.* 1180), who translated from Arabic the corrupted peripatetic work *On Plants*, and thus preserved for us a fragment of a work of the Aristotelian school that would otherwise be lost. Robert and Alfred worked in Spain.

But the greatest and most typical of all the translators from the Arabic was Gerard of Cremona (1114–1187), who spent many years at Toledo and obtained a thorough knowledge of Arabic from a native Christian teacher. He is credited with having translated into Latin no less than ninety-two complete Arabic works. Many of them are of very great length, among them being the *Almagest* of Ptolemy on which Regiomontanus began his work in the fifteenth century, and the enormous *Canon* of Avicenna (980–1037), perhaps the most widely read medical treatise ever penned, editions of which continued to be issued right down to the middle of the seventeenth century. The *Canon* of Avicenna is still in current use in the East.

Contemporary with Gerard of Cremona, and perhaps stimulated by him, were certain native translators. One of these was Domenico Gonzalez (Gundissalinus, fl. 1140), a Christian who rendered into Latin the *Physica* and the *De caelo et mundo* of Aristotle. Another Spaniard, Johannes Hispalensis or Ibn Daud, known to the Latins as Avendeath (fl. 1130–1155), was a converted Jew. Avendeath translated, among many other works, the pseudo-Aristotelian treatise *Secretum secretorum philosophorum* which greatly influenced Roger Bacon, as well as the astronomical works of the Egyptian Jewish writer Messahalah (Ma scha'a Allah = 'What God will', 770–820). This Latin translation of Messahalah long formed the staple popular account of the system of the world under the name of the Englishman John Holywood ('Sacrobosco', d. 1256). Gonzalez and Avendeath, like Gerard, worked at Toledo.

The Sicilian group was less active. The *Optics* of Ptolemy was translated about 1150 by the Sicilian admiral Eugenius of Palermo. He rendered it from the Arabic though he had an effective knowledge of Greek. The great astronomical and mathematical system of Ptolemy known to the Middle Ages as the *Almagest* was

also first translated into Latin from the Arabic in Sicily in 1163 (some twelve years before it was rendered by Gerard at Toledo), and Arabian versions only of the work were available until the fifteenth century. The last translator of Sicilian origin, the Jew Farragut (Farradj ben Selim, Moses Farachi, d. 1285), was a student at Salerno, and his works were among the latest of any influence that issued from that ancient seat of learning. Such later translators were, however, usually less influential, and at the end of the thirteenth century, we may say that the period of important translations was rapidly closing.

§ 5. *Content of Mediaeval Science. The Astrological Clue*

We have now to turn to the actual material thus conveyed to Latin Christendom. It differed rather in degree than in kind from that of the earlier Dark Age and from that of the age of Arabian infiltration. The systems differed in the extent to which certain logical conclusions from the premises provided were pushed, and in the amount to which each was influenced by certain theological conceptions.

In the late classical age there had developed the Stoic system of thought, which divided with Neoplatonism and Epicureanism all the more philosophical minds of the ancient world. This Stoic philosophy assumed that man's fate was determined by an interplay of forces, the nature and character of which were, in theory at least, completely knowable. The microcosm, man, reflected the macrocosm, the great world that lay around him. But how and to what extent did the one reflect the other? In seeking to determine these points Stoicism, like Neoplatonism and the other philosophical systems of the classical twilight, gleaned from many sources material which it passed on

in a corrupted state to the Latin West. In a somewhat less imperfect form such material lingered for centuries in the Byzantine East until, with the great outburst of Islam, it was caught up and elaborated by the Arabic culture. Thus elaborated, it was sent forth a second time to Latin Europe by the process of infiltration and translation.

The astrological conceptions of the Stoics and of the later Christian ages drew both on Plato and on Aristotle. The hylozoism of the *Timaeus*, the doctrine that the universe itself and the matter of which it is composed is living, gave a suggestive outline to the hypothesis of the parallelism of the outer and inner universe. But the main details, on which the hypothesis was based, were drawn from Aristotle, whose views or supposed views as to the structure of the universe formed the framework on which the whole of mediaeval science from the thirteenth century onward was built. Especially Aristotle's conception of the stars as living things, of a nature higher and nobler than that of any substance or being in the spheres below, was a point of departure from which the influence of the heavenly bodies over human destinies might be developed. Changes undergone by bodies on the earth below—all phenomena in fact—were held to be controlled by parallel movements in the heavens above.

The theory carried the matter farther. Taking its clue from the Aristotelian conception of the 'perfection' of the circle among geometrical figures, it distinguished the perfect, regular, circular motion of the fixed stars from the imperfect, irregular, linear motion of the planets. The fixed stars, moving regularly in a circle, controlled the ordered course of nature, the events that proceeded in recurring, manifest, and unalterable rounds, such as winter and summer, night and day, growth and decay. The planets, on the other hand, erratic or at

least errant in their movements, governed the more variable and less easily ascertainable events in the world around and within us, the happenings that make life the uncertain, hopeful, dangerous, happy thing it is. It was to the ascertainment of the factors governing this kaleidoscope of life that astrology set itself. The general outline was fixed, death in the end was sure, and, to the believing Christian, life after it. But there was a great uncertain zone between the sure and the unsure that might be predicted and perhaps avoided, or, if not avoided, its worst consequences abated. It was to this process of insurance that the astrologer set himself, and his task remained the same throughout the Middle Ages. In this hope, *savoir afin de prévoir*, the mediaeval astrologer was at one with the modern scientist.

In the earlier Middle Ages, however, as in the earliest Christian centuries, the world was but God's footstool, and all its phenomena were far less worthy of study than were the things of religion. In the view of many patristic writers the study of the stars was likely to lead to indifference to Him that sitteth above the heavens. This is the general attitude of the fourth and fifth centuries, set forth for instance by Augustine, who speaks of 'those impostors the mathematicians [i.e. astrologers] . . . who use no sacrifice, nor pray to any spirit for their divinations, which arts Christian and true piety consistently rejects and condemns'.

By the sixth and seventh centuries, however, the Church had come to terms with astrology, and Isidore regards it as, in part at least, a legitimate science. He distinguishes, however, between *natural* and *superstitious* astrology. The latter is 'the science practised by the *mathematici* who read prophecies in the heavens, and place the twelve constellations [of the Zodiac] as rulers over the members of man's body and soul, and predict

the nativities and dispositions of men by the courses of the stars'. Nevertheless Isidore accepts many of the conclusions of astrology. He advises physicians to study it, and he ascribes to the moon an influence over plant and animal life and control over the humours of man, while he accepts without question the influence of the dog-star and of comets. He is followed by the other Dark Age writers on natural knowledge, who accept successively more and more astrological doctrine.

With the advent of the Arabian learning the matter was carried farther, and astrology became the central interest. It retained this position until the triumph of the experimental method in the seventeenth century. We cannot here follow the details of the developed astrological scheme. It is enough for our purpose to have observed that the general material law which it implies had become widely accepted in the Middle Ages, and to have traced its passage from antiquity and from the Orient into the thought of the West and of the period of which we are treating.

Especial attention was always paid to the zodiacal signs and to the planets. Each zodiacal sign was held to govern or to have special influence on some region of the body, and each of the planets was held to influence a special organ. The supposed relations of zodiacal signs, planets, and bodily parts and organs, together with their power to produce disease, had been set forth in such late Latin writers as Firmicus Maternus (*c.* 330) and Avienus (*c.* 380) and in innumerable Greek texts. This belief, conveyed to the Dark Age, but much corrupted and attenuated during its course, was brought back again to the West, reinforced and developed, in translations from the Arabic during the scholastic period which followed.

§ 6. *Scholasticism and Science*

Doctrine of this type received into Europe was stamped with the special form of Western thought. Now, it was characteristic of the mediaeval Western thinker that he sought always a complete scheme of things. He was not content to separate, as we do, one department of knowledge or one class of phenomena, and consider it in and by itself. Still less would he have held it a virtue to become a specialist, to limit his outlook to one department with the object of increasing the sum of knowledge in it.

His universe, it must be remembered, so far as it was material, was limited. The outer limit was the *primum mobile,* the outermost of the concentric spheres of which the Aristotelian world was composed. Of the structure and nature of all within the sphere of the *primum mobile* he had been provided with a definite scheme. The self-appointed task of mediaeval science was to elaborate that scheme in connexion with the moral world. This was first especially undertaken by mystical writers working under the stimulus of the new Arabian influence. Such authors as Hugh of St. Victor (1095–1141), who drew on the earlier and more vague Arabian rumours, Bernard Sylvestris (*c.* 1150), who relied on Hermann the Cripple (1013–1054), and Hildegard (1098–1180), who was influenced by Bernard Sylvestris and by other Arabicized writings, all produced most elaborate mystical schemes based on the doctrine of the macrocosm and microcosm. These schemes took into account the form of the world and of man as derived from Arabian sources, and read into each relationship a spiritual meaning. For such an attitude of mind there could be no ultimate distinction between physical events, moral truths, and spiritual experiences. In their fusion of the internal and external universe these mystics have much in common with the

mystics of all ages. The culmination of the process, so far as our period is concerned, is reached with Dante (1265–1321).

But with the thirteenth century new currents of thought set in. Arabian science had at last been won, the scientific works of Aristotle were becoming accessible and gradually entering the curriculum, the universities were firmly established, and there were the beginnings of a knowledge of Greek. A contemporary religious movement of vast importance was the foundation of the mendicant religious orders the activities of which largely replaced those of the monastic Benedictines. Among these new orders were two that specially influenced the Universities, the Dominicans or Black Friars founded at Toulouse in 1215 by the austere and orthodox Dominic (1170–1221) and the Franciscans or Grey Friars founded in 1209 by the gentle and loving Francis of Assisi. The contributions of the Carmelites or White Friars and the Hermits or Austin (Augustinian) Friars were less weighty. The name of Dominic is associated with the terrible extermination of the Albigenses, and the Dominicans (the *Domini canes*, hounds of the Lord) set themselves to the strengthening of the doctrine of the Church and to the extirpation of error. The work of the Franciscans led up more clearly to the scientific revival. During the thirteenth century these two orders provided most of the great university teachers, who occupied themselves in marshalling the new knowledge and making it more accessible. Alexander of Hales (d. 1245) and Robert Grosseteste (d. 1253) were Franciscans, Albertus Magnus (1206–1280) and St. Thomas Aquinas (1227–1274) were Dominicans.

A foremost influence in the revival was the recovery of the writings of Aristotle. It was the interpretation of these works by a few great thinkers that gave to

Scholasticism its essential character. Thus it is that the history of the recovery of the Aristotelian corpus has been a main theme of writers on mediaeval thought for over a century. The first scholastic to be acquainted with the whole works of Aristotle was Alexander of Hales. Albert was the first who reduced the whole philosophy of Aristotle to systematic order with constant reference to the Arabian commentators, while Aquinas remodelled the Aristotelian philosophy in accordance with the requirements of ecclesiastical doctrine. As time went on, the works of Aristotle, at first represented in translations from Arabic, gradually became accessible in renderings direct from the Greek. A very important agent in this process was the Dominican William of Moerbeke (d. 1286).

It is remarkable that this process of codifying the new knowledge, involving as it did a rapid development in the whole mental life, did not early develop a more passionate and more conscious faith in the reality and value of progress in knowledge. The test of such faith, so far as nature is concerned, must be the direct appeal to nature. Yet there is very little evidence of direct observation of nature in the great physical encyclopaedias of the thirteenth century, such as those of the Augustinian Alexander of Neckam (1157–1217), the Dominican Vincent de Beauvais (1190–1264), or the Franciscan Bartholomew of England (*c.* 1260). The fact is that the mediaeval mind was obsessed with the idea of the world as mortal, destructible, finite, and therefore completely knowable both in space and in time. Thus the motive for detailed *research*, in our modern sense of the word, was hardly present. One great Islamic philosopher there was, Averroes (Ibn Roschd, d. 1198), who took an opposite view. His works were available in Latin, but the great ecclesiastics set their face against him, and his theories were adopted by few but Jews.

The mediaeval world thus knew nothing of that infinite sea of experience on which the man of science nowadays launches his bark in adventurous exploration. The task of the writers of these encyclopaedias was rather to give a general outline of knowledge, to set forth such a survey of the universe as would be in accord with spiritual truth. The framework on which this encyclopaedic scheme was built was Aristotle, largely as conveyed by his Arabic commentator Averroes, the philosopher whom the heads of the Church had condemned. Yet it is an amusing reflection on the incompleteness of all philosophical systems that Albert (1206–1280), who perhaps more than any man was responsible for the scholastic world-system, was among the very few mediaeval writers who were real observers of nature. It is, after all, in the very essence of the human animal to love the world around it and to watch its creatures. *Naturam expellas furca tamen usque recurret.* Albert, scholastic of the scholastics, drowned in erudition and the most learned man of his time, has left us evidence in his great works on natural history that the scientific spirit was beginning to awake. As an independent observer he is not altogether contemptible, and this element in him marks the new dawn which we trace more clearly in his successors.

§ 7. *The Dawn of Modern Science. Roger Bacon*

Thus the best of the systematizers among the schoolmen were leading on to the direct observation of nature. Contemporary with Albert (1206–1280) and Aquinas (1227–1274) were several remarkable scholastic writers who form the earliest group with whom the conscious advancement of knowledge was a permanent interest. These men were the first consciously forward-looking scientific thinkers since the fourth century. Perhaps the most arresting of them was Robert Grosseteste (*c.* 1175–

1253), Bishop of Lincoln. Grosseteste determined the main direction of physical investigation in the thirteenth century by his work on *Optics*. He knows something of the action of mirrors and of the nature of lenses. It would appear that he had actually experimented with lenses, and many of the optical ideas of Roger Bacon were taken straight from his master. The main Arabian source of Grosseteste was a Latin translation of the mathematical work of Alhazen of Bazra (965–1038). Another important optical writer whom Alhazen deeply influenced was the Pole Witelo (fl. 1270), an acute mathematical investigator who worked in northern Italy. Roger Bacon was largely dependent on Witelo.

The opposition between the followers of Dominic and of Francis was paralleled by certain very remarkable developments among the Franciscans themselves. There is no stranger and more impressive chapter in the whole history of thought than that of the early history of the Franciscans. Within the memory of men who had known the saintly founder of the order (1181–1226), the 'penitents of Assisi', the 'friars minor', sworn as '*jongleurs* of God' to bring Christ cheerfully to the humblest and the meanest, sworn to possess nothing, to earn their bread from day to day by the work of their own hands, or at need by begging, forbidden to lay by store or to accumulate capital, this order of humble servants of Christ had produced a series of monumental and scholarly intellects. These men not only initiated what bid fair to be a renaissance of science and letters, but also aided in the formation of the bulwark which long resisted the very movement that thus emanated from the order itself. To both parties the English Franciscan houses contributed an overwhelming share. To the former, or scientific party, as we may call it, belonged Robert Grosseteste, Bishop of Lincoln (*c.* 1175–1253), John Pecham, Archbishop of Canterbury (d. 1292),

the elusive Adam Marsh (d. 1257), and above all Roger Bacon (1214–1294). To the latter or theological party are attached the names of Alexander of Hales (d. 1245), Duns Scotus (1265?–1308?), and William of Ockham (d. 1349).

The primary inspirer of the scientific movement was the great Bishop of Lincoln himself, as we learn from his pupil Roger. 'Nobody', says Bacon, 'can attain to proficiency in the science of mathematics by the method hitherto known unless he devotes to its study thirty or forty years, . . . and that is the reason why so few study that science. . . . Yet there were found some famous men, as Robert [Grosseteste] Bishop of Lincoln, and Adam Marsh, and some others, who knew how by the power of mathematics to unfold the causes of all things and to give a sufficient explanation of human and divine phenomena. The assurance of this fact is to be found in the writings of those great men, as, for instance, in their works on the impression [of the elements], on the rainbow and the comets, on the sphere, and on other questions appertaining both to theology and to natural philosophy.' The work of this remarkable group of Franciscans at Oxford extended beyond the sciences to language and literature. There was thus the beginning of a real renaissance of Greek letters which died an early death. After Roger Bacon's death the scientific revival also languished until recalled to life by a second revival of a later century.

It may be convenient to give a summary of the scientific achievements of Roger Bacon, the greatest of the Franciscan group and the first man of science in the modern sense.

1. He attempted to set forth a system of natural knowledge. This system was far in advance of his time, and its basis was observation and experiment. He was clearly the first man in modern Europe of whom this can be said.

2. He was the first to see the need for the accurate study of foreign and ancient languages. He attempted grammars of Greek and Hebrew along definite scientific lines. He also projected a grammar of Arabic. Moreover, he laid down those lines of textual criticism which have only been developed within the last century.

3. He not only discussed the nature of the experimental method, but was himself an experimenter. His writings are important for the development of the following sciences:

(*a*) *Optics.* His work on this subject was a text-book for the next two centuries. He saw the importance of lenses and concave mirrors, and showed a grasp of the mathematical principles of optics. He described a system equivalent to a two-lens apparatus, and there is trustworthy evidence that he actually used a compound system of lenses equivalent to a telescope.

(*b*) *Astronomy* was Bacon's perpetual interest. He spent the best part of twenty years in the construction of astronomical tables. His letter to the Pope in favour of the correction of the calendar, though unsuccessful in his own day, was borrowed and reborrowed, and finally, at third-hand, produced the Gregorian correction.

(*c*) *Geography.* He was the first systematic geographer of the Middle Ages. He gave a systematic description of Europe, Asia, and part of Africa. He collected first-hand evidence from travellers in all these continents. His arguments as to the size and sphericity of the earth were among those that influenced Columbus.

(*d*) *Mechanical Science.* Suggestions by him include the automatic propulsion of vehicles and vessels. He records a plan for a flying machine.

(*e*) *Chemistry.* The chemical knowledge of his time was systematized in his tracts. His description of the composition and manufacture of gunpowder is the earliest

that has reached us. It is clear that he had worked out for himself some of the chemistry of the subject.

(*f*) *Mathematics.* His insistence on the supreme value of mathematics as a foundation for education recalls the attitude of Plato. It was an insistence that the method of thought was at least as important as its content.

Summed up, his legacy to thought may be regarded as accuracy of method, criticism of authority, and reliance on experiment—the pillars of modern science.[1]

Bacon was not an isolated phenomenon, but an important link in the chain of scientific development. But during the century after Bacon, though his mathematical and philosophical works were still studied in the schools, the greatest advances were to be found among the physicians. Of medical men the last half of the thirteenth and the first half of the fourteenth century exhibit an especially brilliant group. Bologna had possessed a medical school since the twelfth century, and had inherited the learning of Salerno. At Bologna had worked Hugh of Lucca (d. 1252?) and his son or pupil Theodoric (1206–1298). Here surgery may be said to have been born again with the practice of Roland of Parma (*c.* 1250), the successor and faithful follower of Roger of Salerno (*c.* 1220). At Bologna, above all, William of Saliceto (1201–1280) established a practical method of anatomization which was inherited by Mondino da Luzzi (1276–1328), whose work based on translations from the Arabic text of Avicenna became the general anatomical text-book of the later Middle Ages. By the fourteenth century the practice of dissection of the human body had become well recognized.

[1] It is not inappropriate to point out here that this country has not yet been able to raise funds for a national edition of the writings of its first man of science. Many of the works of Roger still remain unpublished. The writer of this article will be glad to receive contributions for this object.

At the end of the thirteenth century the ancient foundation of the medical school of Montpellier was coming to the fore. The Catalan Arnald of Villanova (1235–1311), one of the most remarkable personalities of mediaeval medicine, taught there. Arnald was not only one of the earliest exponents of the Hippocratic method of observing and carefully recording symptoms of actual cases of disease, but he also deeply influenced alchemy. That study was effectively of Arabian origin so far as the modern world is concerned. It begins in 1144 with the translation into Latin from Arabic by Robert of Chester of the *De compositione alchemiae* which Morienus Romanus, a contemporary hermit of Jerusalem, had 'edited for Calid, king of the Egyptians'. Alchemy had taken its rise with a real effort to understand the properties of metals, prompted by the hope of transmuting the baser into the more precious. Like other mediaeval studies, it became linked with astrology, and the 'seven metals' were each of them controlled or influenced by the 'seven planets' much in the same way as were the organs of the human body. Of such ideas Arnald was a prolific exponent. He had a knowledge of both Arabic and Hebrew. A student at Naples and Salerno, a traveller in Italy, Sicily, France, and Spain, he served as medical adviser to the Papal Curia both at Rome and Avignon, and was employed as ambassador on more than one special mission. Arnald influenced politics no less than learning, and ended his adventurous life at sea. A character somewhat similar to Arnald was the Majorcan Raymond Lull (1235–1313), who was learned in oriental languages and deeply influenced Alchemy.

§ 8. *Humanism*

In outlook no less remarkable than Arnald was the heretical Peter of Abano (1250–*c.* 1318). He earned a reputation as a magician, and his natural death saved him from the hands of the Inquisition. His body is said to have been exhumed and burned. Peter—who was a most voluminous writer—had a knowledge of Greek, acquired at Constantinople, and he translated works from that language. He was a professor at the University of Paris and later at Padua in the generation which followed that in which the newly won Aristotelian works on physics had entered the curriculum. His greatest and best-known work, the *Conciliator*, expresses his mediation between the now commencing humanistic Greek school and the Arabists. From that work we learn that he had come into contact with the great traveller Marco Polo (*c.* 1254–1324). Among the views of Peter of Abano that are most worth record may be mentioned his statements that the air has weight, that the brain is the source of the nerves and the heart of the vessels—all ideas that were novel in his time. He made a remarkably accurate measure of the length of the year as 365 days, 6 hours, 4 minutes.

The second half of the fourteenth century, perhaps owing to social disturbance and notably to the effects of the Black Death (1347–1349), shows a distinct falling off in the intellectual advance. In medicine the most noteworthy name is that of Guy de Chauliac of Montpellier (1300–1370), the most influential of all the mediaeval surgeons. Outside the ranks of the physicians the most striking figure in fourteenth-century science is probably the French Jewish philosopher Levi ben Gerson (1288–1344). His work on astronomy was important as illustrating the consciousness of a growing discontent with the Ptolemaic system of the universe.

With the fourteenth century appeared too a great movement, the hand of which is still heavy on our own day. Humanism was born. Historians have perhaps linked the humanistic movement too intimately with a knowledge of the Greek language. Instances of knowledge of that language in the West can, however, be adduced far back into the Dark Ages (e. g. John Scot Erigena, *c.* 850), while many of the greatest of the humanists, including Petrarch himself (1304–1374), were without such knowledge. It is worth noting too, as linking humanism with the Middle Ages, that Petrarch's epistolary style was still moulded on St. Augustine rather than on Cicero.

The backward-looking habit, strong in man from his nature and strengthened by the teaching of the Christian religion, was yet further enforced by the humanists. From Petrarch onward they were ever brooding on the past that had been Greece and Rome. Yet even from the first, the humanists had the sensation too of being *builders*, so that their glance was at times turned away from the past and towards what was to come, nay, what was in the act of becoming. Roger Bacon and a few isolated souls had had this double vision, but for a whole school to possess it was something new. In his *Book of memorable things* Petrarch says outright, 'Here stand I as though on a frontier that divides two peoples, looking both to the past and to the future'. While studying the classics some of these very men were indeed visibly forging new intellectual weapons, those national vernaculars that have made modern literature and thought possible. It is no mere coincidence that Boccaccio (1313–1375), friend and contemporary of Petrarch, should have been at once the first modern literary man to study Greek and the first great master of Italian prose.

We must note, however, that save for reverence for the one supreme poet in their own tongue, Dante (1265–1321),

the backward gaze of the Italian humanist is always fixed on the more distant classical past, not on the nearer period that came to be regarded as a yawning chasm, an abyss across which he sought to reach back to the thought of antiquity. To him the Middle Ages seemed real enough and dark enough. It stood for the period during which the sweet Greek literature had been ignored. Even in this new age it could be understood by few except in Latin dress, and the work of translation remained somewhat of a specialist's occupation. To the end of the fifteenth century an effective knowledge of Greek continued to be a rarity even among scholars, and we may point to some of the most important teachers of the sixteenth century who were still without it.

The great influence of the masterpieces of Greece, therefore, was then as now something indirect, often conveyed through translators and special interpreters, a subtle thing that influenced men's way of thinking rather than the actual content of their minds. The mere capacity for translation from the Greek goes back, as we have seen, to the eleventh century, the ninth century, or even beyond. It can therefore hardly have been simply the discovery of the actual Greek language which brought about the revival of letters. But if the knowledge of Greek goes back so far, can we speak of a real Renaissance at all? How can we account for the change of heart that came over the world when humanism was born? Or is that change of heart but an illusion, a difference of degree rather than of kind in a world where everything is in a state of becoming?

Some answer to this absorbing question we may glean by comparing the earlier Greek works which came to the West to those of later advent. The general character of the earlier translations was determined by the outlook of a world becoming ever more deeply Arabicized. Islam,

the inheritor of antiquity, entered into the enjoyment of its legacy with great spirit, but with a taste already fixed. The literary and artistic works were debarred by a definite theological standpoint. Homer and Hesiod, Sophocles and Euripides, Greek Art and Greek Architecture were chapters as closed and forbidden to Islam as to early Christian Europe. It was the philosophical, the scientific, the mathematical, the medical works that made an appeal. These gave an illusory impression of completeness to life with which Islam long rested content. It was these very works that were the first to be rendered into Latin from the Arabic, and the Latin taste being thus determined it was similar works that were the first to be turned into Latin direct from the Greek.

Such material—and it is bulky and intricate enough—represents the Western access to Greek wisdom before the fourteenth century. It does not lack variety, but it lacks life. They err who think the discovery of the humanists was the Greek language—here the humanists were but followers where others had been pioneers. It is something much deeper and more fundamental which they have handed on to us, something the nature of which they hardly knew and the meaning of which they missed in their enthusiasm. The humanists discovered the literary works of antiquity. In them they became absorbed to the exclusion of all else. The humanist eagerness passed into a literary vogue, and long cast the blight of a purely literary education on the modern world. The barren striving after form as distinct from substance, the miserable and slavish imitativeness that is no flattery but an insult to its model, these features, exhibited typically in the literature of the late Empire, were repeated by the humanists as they have been often repeated in modern times.

The humanist then did not give us the knowledge of a language nor did he even give an insight into the life

of antiquity. What the humanist really gave was a something which, added to the heritage already there, made possible a completer reconstruction of the Greek spirit. That reconstruction, indeed, he was never able to make; it was the succeeding generations that made it for themselves. With that reconstruction Greece lived again, the modern world was ushered in, and modern science, art, literature, and philosophy were born. It is an illuminating reflection and one not without bearing on our present state that both the mediaeval heritage of Greek science and the Renaissance heritage of Greek literature proved barren by themselves. It was not until the one fertilized the other that there was real and vital growth. Modern thought, modern science, modern art, and modern letters are the offspring of that union.

§ 9. *The Science of the Renaissance*

The humanists as a class did not exhibit great sympathy with the scientific outlook. Their interests were literary and their peculiar aversion was the Arabist tendency of the Middle Ages that they were leaving behind. That Arabist tendency was very largely expressed in the ancient scientific and philosophical themes, some of which we have discussed in outline. In the movement initiated by Roger Bacon in the thirteenth century a new element had been introduced. That movement had fallen into the background after Roger's death. It had not entirely died, but it had become 'quietist'—if the expression may be used in this connexion—a part of the seldom-expressed faith of a small band of philosophically-minded recluses. Faith in the appeal to nature was at last to find more open expression. With the fifteenth century, discontent with the entire mediaeval scientific scheme becomes more generally obvious, and we perceive a first hint of the idea

that it may be possible to adjust theory by means of experiment.

The earliest suggestion is made by a man of high genius and scholarship, the Rhinelander Nicholas of Cues (1401–1464), who became a cardinal and made a fruitless attempt to reform the calendar. The philosophical basis of the experimental suggestion of Nicholas of Cues is set forth in his book *De docta ignorantia,* which has nothing to do with the absurdity of erudition, as its name might be thought to imply, but concerns itself with acknowledged ignorance, i. e. with the inability of the human mind to conceive the infinite. His theoretical views led him to a belief that the earth is moving, though he attained to no genuine heliocentric theory. He records a careful experiment on a growing plant—afterward pirated by the seventeenth-century writer van Helmont (1577–1644)—proving that it absorbs something of weight from the air. This is the first biological experiment of modern times, and incidentally the first formal proof that the air has weight. In another work, *De staticis experimentis,* Nicholas shows that he knew how to apply the experimental method in detail, and he suggests in outline many investigations which were not taken in hand until the time of Galileo 150 years later.

The tradition of the combination of scholarship and observation that Nicholas had started was carried on by several astronomers in the second half of the fifteenth century. For part of this work we are indebted to the far-sightedness of another Cardinal, Johannes Bessarion (1389–1472), a Greek by birth, who was equally anxious to aid the progress of astronomical knowledge and to diffuse Greek literature in the West. Bessarion's friendship, extended to the two German astronomers Purbach and Regiomontanus, made possible their work which formed the foundation of that of Copernicus.

George Purbach (1423–1461) followed with great avidity the study of Ptolemy. He died prematurely and had only translations from the Arabic on which to base his work. He improved on his original, however, by calculating a table for every 10 minutes, using sines instead of chords.

Johannes Müller (1436–1476) of Königsberg (=*King's mountain*), usually known from his birthplace as Regiomontanus, though his life was hardly longer than that of Purbach, had the good fortune to work on Greek originals. He produced the first systematic treatise on trigonometry and a table of sines for every minute and of tangents for every degree. He edited too the *Epitome of Ptolemy* which Purbach had left behind him in an imperfect state. He died at Rome, whither he had been summoned by the Pope to aid in the long-contemplated reform of the Calendar. The important works of Regiomontanus were only published after his death. His name has become associated with an ill-founded legend that he taught the heliocentric view of the solar system before Copernicus. The statement has been made of several other contemporaries, Leonardo da Vinci (1452–1519) among them. It has been verified, however, for only one of them (Celio Calcagnini, 1479–1541), who perhaps borrowed the idea from Copernicus.

The most remarkable philosophical teacher of the Renaissance was perhaps Pietro Pomponazzi (1462–1525), a writer who, in many respects, foreshadows the new period and the work of its great philosopher Francis Bacon. Pomponazzi was a physician who became a professor of philosophy and devoted himself to the exposition of what he believed to be the teaching of Aristotle. Though incapable of interpreting Aristotle to his hearers from the original Greek, Pomponazzi was yet a very spirited and original teacher, of great independence of thought. He was wholly divorced from the religion of his

day, and he died repudiating the hope of Christianity. But Pomponazzi represents a movement of far more importance than any mere school of Aristotelian interpretation. He stands for *Naturalism*, for the attempt to explain the World and all that it contains on the basis of known or discoverable laws. That many of the laws considered by him as demonstrated now seem absurdities, that on insufficient evidence he regarded certain earthly events as related to the movements of the heavenly bodies with the same assurance that we now ascribe them to climate or meteorological conditions, these are errors in the application of his method that need not affect our judgement of the importance of his philosophical position.

The Renaissance of Letters was contemporary with the Renaissance of Art, and the artists had also their reaction upon scientific thought. The great painters had begun to study nature more closely. Antonio Pollaiuolo (1429–1498) and Andrea del Verrocchio (1435–1488), among others, had made careful investigations of surface anatomy, while the exquisite figures of plants in the pictures of Sandro Botticelli (1444–1510) mark him out as a very accurate observer. There was, however, one artist of the time who takes a quite peculiar place among students of nature. Leonardo da Vinci (1452–1519) stands for many as the turning-point of the Renaissance into modern times.

It would be impossible to give in a paragraph the titles to fame of one of the very greatest geniuses that the human race has produced. The marvellous rapidity of his insight, the sureness of his intuitions, and his extreme versatility made earlier students place Leonardo in an isolated and almost non-human position. His very limitations, moreover, while they have increased the apparent gulf which separates him from other men, have

hampered the comprehension of his mind. Isolated he remains by the loftiness of his genius, but more prolonged study has revealed many of the sources of his knowledge and some of his methods of work.

To understand anything of Leonardo's scientific work and of its fate we must however recognize his defects. Leonardo's great limitation was on the literary and linguistic side. He had no gift for language and did not acquire even an elementary knowledge of Latin till well on in life. He had no power of literary expression. The language that he employs is that of a Florentine shop-keeper of the lower class. He created no great phrase or saying. In his note-books his sentences are usually ungrammatical and often unfinished. Even allowing for the purely private nature of these memoranda, it is yet fairly evident that in a literary sense he was incoherent. The very rush of his ideas seems to have obstructed the natural channels of their expression. Of him his biographer Vasari quotes with admirable point the lines of Petrarch:

E l' amor di saper che m' ha si acceso
Che l' opera e retardato dal desio.

My love of knowledge so inflamed me
That my work was retarded by my very desire.

With what we now know of Leonardo the question may reasonably be raised whether his art did, in fact, consume the major part of his energy and his thoughts. Among the great artists he was notorious for the smallness of his output and for the extreme slowness with which he worked. On the other hand, he left behind him a vast mass of papers, about 5,000 leaves of which have survived. These contain evidence not only of a unique scientific insight but of a tireless industry which is almost incredible. He covers the whole field of science from mathematics to physiology, and there is nothing that he touches which

he does not illuminate. To give but a few scattered instances: he presents us not only with a model of a flying machine but with an invention of a helicopter, and he analyses the nature of flight of birds in a way that has only been surpassed during the last few years; he has a design for a parabolic compass on a principle that was not adopted till late in the seventeenth century; he hints at a heliocentric view of the world; he has admirable drawings of quick-firing and breech-loading guns; he has mastered the theoretical principles of perspective; he sets forth the homologies of the vertebrate skeleton; he has passages which suggest the laws of motion; and his anatomical and embryological standpoint was not passed in certain respects for hundreds of years.

Leonardo may be linked with his time by tracing some of his scientific ideas back to his predecessors. The break in continuity is much more marked if we seek to trace them forwards. He had indeed very little influence on the science of the age which immediately followed him. Save in certain ideas and drawings of a few sixteenth-century anatomists leading on to Vesalius, the scientific work of Leonardo was without effect until modern times. If Leonardo be regarded as the topmost peak of the Renaissance, that peak, continuous with a long range of mighty mountains on one side, terminates in an almost sheer precipice on the other.

Before we quite part with the Renaissance we must consider another remarkable character whose life-course was almost as isolated and aberrant as that of Leonardo. The Swiss writer Aurelius Philippus Theophrastus Bombastus von Hohenheim, commonly known as Paracelsus (1493–1541), was a person of violent, dramatic and repellent temper, a born rebel whose iconoclasm doubtless did something to deter men from the worship of the old idols. His symbolic act of burning the works both of the

Greek Galen and of the Arab Avicenna, as an introduction to his lecture course at Basel, typified the position of the independent investigators of the generation that immediately followed him. A writer of excessive obscurity, an obscurity of language, of form, and of thought, very few have claimed the privilege of penetrating to his full meaning, and those few have nearly all been infected with some of the defect of expression from which the master suffered. There is, however, a general agreement among the learned and nebulous band of Paracelsists that their hero did indeed foreshadow the 'new instauration'. His aim was to see the world in the 'Light of Nature'. That light of his is dimmed for us because of his extreme gullibility in some matters, his violence and self-contradiction in others, and the involved and mystical presentment in all. 'Nature' contained for him the influence of the stars upon the lives of men and many other mysterious phenomena then generally credited. He believed still in a relation of microcosm and macrocosm—as in a residual sense we all do—but his free modification of that theory paved the way for its rejection in the generation which followed.

§ 10. *The Great Instauration*

Francis Bacon (1561–1620), coming at the very end of our period, grasped the nature of the truth that had been struggling to birth since the days of his great namesake. He called it the *Instauratio Magna*, the great restoration. Of him a modern enthusiast for research (Mark Pattison) has written, 'the great instaurator of all knowledge, in preaching the necessity of altering the whole method of knowing included the method of "teaching to know"'. Of the reformers of the method of teaching to know, two stand at the very threshold of the new era, Nicholas Copernicus and Andreas Vesalius.

The Pole Nicholas Copernicus (1473–1543), despite the vast change that was introduced in his name into men's ideas, was himself more in the line of such comparatively conservative scholars as Nicholas of Cues and Regiomontanus than the more revolutionary Leonardo or Paracelsus. No man was ever more 'academic', and he continued to attend university courses until over thirty years of age. He studied at several Italian universities, giving attention to classics, mathematics, astronomy, medicine, law, and theology. His skill in painting suggests that he had that type of visualizing imagination frequently associated with scientific power.

Copernicus was not, however, a first-hand observer on any large scale. He had, it is true, taken a number of observations of eclipses and oppositions of planets, but for the most part his results were obtained in the study. He tells us that he was induced to seek a new theory of the heavenly bodies by finding that mathematicians differed among themselves on this subject. He had counted up the various motions of the heavenly bodies involved in the old system and concluded that some essential factor had been missed. He therefore turned to antiquity and learned from Cicero—who quotes Hiketas—and Plutarch that some among the ancients were of the same opinion.

'Occasioned by this,' he says, 'I decided to try whether, on the assumption of some motion of the earth, better explanations of the revolutions of the heavenly spheres might not be found. Thus assuming the motions which I attribute to the earth . . . I have found that when the motions of the other planets are referred to the circulation of the earth and are computed for the revolution of each star, not only do the phenomena necessarily follow therefrom, but the order and magnitude of the stars and of all their orbs and the heaven itself are so connected that in no part can anything be transposed without confusion to the rest and to the whole universe.'

In this new scheme the ancient theory of the uniform circular motion of the heavenly bodies was still retained. Since it involved the retention of the theory of epicycles as well as the displacement of the sun from the true centre of the planetary orbs, the simplicity of the scheme was only apparent and comparative.

Vesalius (1514–1564) was in almost every respect a contrast to Copernicus. Young, ardent and combative, his life's work was wellnigh complete at twenty-eight, and its effective and creative part was crowded into the four years that preceded the publication of the *Fabrica* in 1543. The contents of that great work were delivered in the form of lecture-demonstrations to crowded audiences. It contains an enormous number of first-hand observations which must have been accumulated while working under the most extreme pressure. Vigorous and fearless in the demonstration of observed fact, Vesalius becomes more timid and less effective in the discussion of theory, and he leaves the Galenic physiology practically intact. He was a man of the laboratory and lecture-room rather than of the study, and reflection was not the source of his power. Yet even his observations are by no means completely free from traditional bias. Thus some of the poses of the figures and the treatment of the skeletons in his book have been shown to be derived from scholastic sources, and there are anatomical structures figured by him which are to be found in the mediaeval tradition, but not in the human body. There are important points which he may have derived by tradition from Leonardo and the artist-anatomists of the previous generation. Taken as a whole, his work is, however, one of the most marvellous efforts of scientific observation that has ever been launched upon the world.

A word must be said as to the point of view of Vesalius. Nowadays the student's dissection-manual figures for

him the anatomy of the dead. Vesalius working in Italy in the sixteenth century was in the midst of a country of artists. He thinks always of the living body and seeks to restore the anatomy of the part into its form when living. The dramatic poses of his corpses and the landscape with which each is provided is no piece of idle artistry. It is a part of his scheme. Nor does he think so much of the actual body he is dissecting as of the idea towards which God is tending in us all. Each body is, as it were, one of that supreme artist's 'studies' for an ideal and final work of art. It is the anatomist's duty to attain as near as he can to that ideal.

The work of Vesalius was carried farther by a number of investigators in the latter part of the sixteenth century, but by none with greater skill and intensity than Hieronymus Fabricius ab Aquapendente (1537–1619), a successor of Vesalius in the chair at Padua, where he taught for over sixty years and where William Harvey (1578–1657) was his pupil. Fabricius was one of the most successful and stimulating of medical teachers and he added an enormous number of facts to the sum of anatomical and physiological knowledge. As an investigator, however, he lacked, like all his contemporaries, complete speculative freedom. For that the time was still hardly ripe, and his physiology was still largely Galenic. While he provided many of the observations on which the view of the circulation of the blood was built, his vision remained obscured by the traditional outlook. It was left to his great English pupil to enunciate the basic doctrine of modern physiology in the next century. The grasp of Galen was weakening, but it had not yet wholly relaxed.

The mentality of Tycho Brahe (1546–1601), the greatest astronomer of the second half of the sixteenth century, was not dissimilar to that of Fabricius, its greatest anatomist. Tycho, like Fabricius, was a first-class observer, but,

like him, weak and timid in drawing conclusions. By means of newly designed but simple apparatus employed with exquisite skill, Tycho attained an unprecedented degree of accuracy in astronomical observation. His records were employed later by his colleague Johann Kepler (1571–1630). These observations aided Kepler to purge the Copernican hypothesis of the traditional notions concerning the movements of the heavenly bodies in circles. The circles were replaced by ellipses and modern astronomy was born.

The year 1600 is associated with two important events in the history of science, which mark it out as the final parting of the ways. In that year Giordano Bruno (1548–1600), a profound student of the works of Nicholas of Cues and an ardent follower of Copernicus, suffered martyrdom at the stake. In that year William Gilbert (1540–1603) produced his work *On the magnet, on magnetic bodies and on the earth as a great magnet, a new physiography*[1] *demonstrated by many arguments and experiments.* The work is the first great scientific treatise published in England, but it is much more. It is a landmark in the history of science as a whole. Gilbert accepts fully the Copernican view of a heliocentric world and he speculates fearlessly on observed conclusions. Above all, as the title of the work tells, his views are *demonstrated by arguments and experiments.* It is a distinction of which he never loses sight, and he is careful to record exactly and by a special device his own personal experiences. These are clearly separated from his arguments and from the experiences of others. The book has the form and spirit of a modern scientific treatise.

We have now left utterly behind the Middle Ages and all their works and ways. The old hypothesis of the

[1] The word he uses is *physiologia,* which is best translated by our word *physiography.*

macrocosm and microcosm was no longer possible to those who had studied and understood the works of Copernicus and Vesalius. Men no longer studied macrocosm and microcosm as such, but they became physicists or physiologists, taking each of them a separated portion of the universe for special study. This disposition to base opinion on observation, involving separation of nature into departments, characterizes the modern method and distinguishes it from the mediaeval. The dawn was past and it was the risen sun that Harvey and Galileo saluted, and in the light of which Francis Bacon and Descartes prophesied.

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VI

THE FIRST PHYSICAL SYNTHESIS

A. N. WHITEHEAD

THERE are in the history of civilization certain dates which stand out as marking either the boundaries or the culminations of critical epochs. It is true that no epoch either commences, ends, or sums itself up in one definite moment. It is brought upon the stage of reality in the arms of its predecessor, and only yields to its successor by reason of a slow process of transformation. Its terminals are conventional. Wherever you choose to fix them, you can be confronted with good reasons for an extension or contraction of your period. But the meridian culmination is sometimes unmistakable, and it is often marked by some striking events which lend an almost mystic symbolism to their exact date. Such a date is the year 1642 of our epoch, the year in which occurred the death of Galileo and the birth of Newton. This date marks the centre of that period of about 100 years, during which the scientific intellect of Europe was framing that First Physical Synthesis which has remained down to our own times as the basis of science. The development of modern Europe from the world of the Renaissance and the Reformation is unintelligible in its unique importance without an understanding of the achievements of these two men. The great civilizations of Asia and of the classical times in the Mediterranean had their epochs of artistic and literary triumph, of religious reformation, and of active scientific speculation. But it was the fortune of modern Europe that during the

seventeenth century, amid a ferment of scientific speculation, two men, one after the other, appeared, each with a supreme gift of physical intuition, with magnificent powers of abstract generalization, and each with subsidiary endowments exactly suited to the immediate circumstances of the scientific problem, this one a supreme experimentalist and enough of a mathematician, and that one a supreme mathematician and enough of an experimentalist. Archimedes left no successor. But our modern civilization is due to the fact that in the year when Galileo died, Newton was born. Think for a moment of the possible course of history supposing that the life's work of these two men were absent. At the commencement of the eighteenth century many curious and baffling facts of physical science would have been observed, vaguely connected by detached and obscure hypotheses. But in the absence of a clear physical synthesis, with its overwhelming success in the solution of problems which from the most remote antiquity had excited attention, the motive for the next advance would have been absent. All epochs pass, and the scientific ferment of the seventeenth century would have died down. Locke's philosophy would never have been written; and Voltaire when he visited England would have carried back to France merely a story of expanding commerce and of the political rivalries between aristocratic factions. Europe might then have lacked the French intellectual movement. But the Fates do not always offer the same gifts twice, and it is possible that the eighteenth century might then have prepared for the western races an intellectual sleep of a thousand years, prosperous with the quiet slow exploitation of the American continent, as manual labour slowly subdued its rivers, its forests, and its prairies. I am not concerned to deny that the result might have been happier, for the chariot of Phoebus is a dangerous

vehicle. My only immediate thesis is that it would have been very different.

The forms of the great works by which the minds of Galileo and Newton are best known to us bear plain evidence of the contrast between their situations. In his book entitled, *The Two Systems of the World in Four Dialogues*, and published in 1632, Galileo is arguing with the past; whilst in his *Mathematical Principles of Natural Philosophy*, published in 1687, Newton ignores old adversaries and discussions, and, looking wholly to the future, calmly enunciates definitions, principles, and proofs which have ever since formed the basis of physical science. Galileo represents the assault and Newton the victory. There can be no doubt but that Galileo is the better reading. It is a real flesh and blood document of human nature which has wedged itself between the two austere epochs of Aristotelian Logic and Applied Mathematics. It was paid for also in the heart's blood of the author.

The catastrophe happened in this way: most unfortunately His Holiness, the reigning pope, in an entirely friendly interview after the Inquisition had forbidden the expression of Copernican opinions, made use of the irrefutable argument that, God being omnipotent, it was as easy for him to send the sun and the planets round the earth as to send the earth and the planets round the sun. How unfortunate it is that even an infallible pontiff and the greatest of men of science, with the most earnest desire to understand each other, cannot rid themselves of their presuppositions. The pope was trembling on the verge of the enunciation of the relativity of motion and of space, and in his Dialogues there are passages in which Galileo plainly expresses that same doctrine. But neither of them was sufficiently aware of the full emphasis to be laid upon that truth. Accordingly the

next precious ten minutes of the conversation in which Galileo might have cleared away the little misunderstanding were wasted, and as a result there ensued for the world's edification the persecution of Galileo and a clear illustration of the limits of infallibility. The true moral of the incident is the importance of great men keeping their tempers. Galileo was annoyed—and very naturally so, for it was an irritating sort of argument with which to counter a great and saving formulation of scientific ideas. Unfortunately he went away and put the pope's argument into the mouth of Simplicius, the man in the Dialogues who always advances the foolish objections. It is welcomed in the following speech by the leading interlocutor, Salviatus—I give it in the seventeenth-century translation of Thomas Salusbury: 'This of yours is admirable, and truly angelical doctrine, to which very exactly that other accords in like manner divine, which whilst it giveth us leave to dispute, touching the constitution of the world, addeth withall (perhaps to the end that the exercise of the minds of men might neither be discouraged nor made bold) that we cannot find out the works made by his hands. Let therefore the Disquisition permitted and ordained us by God, assist us in the knowing, and so much more admiring his greatness, by how much less we find ourselves too dull to penetrate the profound abysses of his infinite wisdom.'

At this point the Dialogues end. Galileo always protested that he had meant no discourtesy. But the pope, even if his infallibility tottered, was here assisted by the gift of prophecy and smelt Voltaire. Anyhow in his turn he lost his temper and afterwards remained the bitter enemy of Galileo.

Galileo's supreme experimental genius is shown by the way in which every hint which reached him is turned to account and immediately made to be of importance.

He hears of the telescope as a curiosity discovered by a Dutch optician. It might have remained a toy, but in his hands it created a revolution. He at once thought out the principles on which it was based, improved upon its design so as to obviate the inversion of objects, and immediately applied it to a systematic survey of the heavens. The results were startling. It was not a few details that were altered, but an almost sacred sentiment which fell before it. I have often thought that the calmness with which the Church accepted Copernicus and its savage hostility to Galileo can only be accounted for by measuring the ravages made by the telescope on the sacred doctrine of the heavens. It was then seen too late that the Copernican doctrine was the key to the position. But Galileo's Dialogues plainly show that it was not the movement of the earth but the glory of the heavens which was the point at issue. It must be remembered that the heaven, which Christ had taught is within us, was by the popular sentiment of mediaeval times placed above us. Accordingly when the telescope revealed the moon and other planets reduced to the measure of the earth, and the sun with evanescent spots, the shock to sentiment was profound. It is the characteristic of shocked sentiment in the case of men whose learning surpasses their genius that they begin to quote Aristotle. Accordingly Aristotle was hurled at Galileo.

The Dialogues are the record of the contemporary dispute between Galileo and the current Aristotelian tradition, and the end of the discussion was the creation of the modern scientific outlook of which Galileo was the first perfect representative—somewhat choleric but entirely whole-hearted.

So far we have been endeavouring to appreciate the climate of opinions amid which Galileo's life was passed—and you will remember that no climate is composed of

a succession of uniform days, especially in its spring-time. A judicious selection could affix almost any label to the thought of the seventeenth century. What we have to keep in our minds is that at its beginning, so far as science was concerned, men knew hardly more than Aristotle and less than Archimedes, while at its end the main positions of modern science were firmly established.

I will now endeavour to explain the main revolutionary ideas which Galileo impressed upon his contemporaries. The first one was the doctrine of the uniformity of the material universe. This doctrine is now so obvious to us that we can only think of it in the attenuated form of discussions on miracles or on the relations of mind and matter. But in Galileo's time the denial of uniformity went much deeper than that. The different regions of Nature were supposed to function in entirely different ways. This presupposition led to a style of argument which is foreign to our ears. For example, here is a short speech of Simplicius, the upholder of the old Aristotelian tradition in Galileo's Dialogues, chosen almost at random:

Aristotle, though of a very perspicacious wit, would not strain it further than needed: holding in all his argumentations, that sensible experiments were to be preferred before any reasons founded upon strength of wit, and said those which should deny the testimony of sense deserved to be punished with the loss of that sense; now who is so blind, that sees not the parts of the Earth and Water to move, as being grave, naturally downwards, namely, towards the centre of the Universe, assigned by nature herself for the end and term of right motion *deorsum*; and doth not likewise see the Fire and Air to move right upwards towards the Concave of the Lunar Orb, as to the natural end of motion *sursum*? And this being so manifestly seen, and we being certain, that *eadem est ratio totius et partium*, why may we not assert it for a true and manifest proposition, that the natural motion of the Earth is the right motion *ad medium*, and that of the Fire, the right *a medio*?

In this passage we note that different functions are assigned to the Centre of the Universe to which the Earth or any part of it naturally moves in a straight line, and to the Concave of the Lunar Orb (to which Fire naturally moves in a straight line). The idea of the neutrality of situation and the universality of physical laws, regulating casual occurrences and holding indifferently in every part, is entirely absent. On the contrary, each local part of nature has its one peculiar function in the scheme of things. It is a fine conception: the only objection to it is that it does not seem to be true. I am not sure, however, that the Einstein conception of the physical forces as being due to the contortions of space-time is not in some respects a return to it.

But let us see how Galileo in the person of the interlocutor, Salviatus, answers this speech of Simplicius. His answer is somewhat long, and I only give the relevant part:

> . . . Now, like as from the consentaneous conspiration of all the parts of the Earth to form its whole, doth follow, that they with equal inclination concur thither from all parts; and to unite themselves as much as is possible together, they there physically adapt themselves; why may we not believe that the Sun, Moon, and other mundane Bodies, be also of a round figure, not by other than a concordant instinct, and natural concourse of all the parts composing them? Of which, if any, at any time, by any violence were separated from the whole, is it not reasonable to think, that they would spontaneously and by natural instinct return? and in this manner to infer, that the right motion agreeth with all mundane bodies alike.

Note that in this answer Galileo, in the person of Salviatus, entirely ignores any peculiar function or property to be assigned to a Centre of the Universe or to a Concave of the Lunar Orb. He has in his mind the conceptions of modern science, in that the Earth, the

Moon, the Sun, and the other planets are all bodies moving in an indifferent neutral space, and each attracting its own parts to form its whole—or, as Salviatus puts it, 'the consentaneous conspiration of all the parts of the Earth to form its whole'.

Evidently Galileo is very near to the Newtonian doctrine of Universal Gravitation. But he is not quite there. Newton enunciates the doctrine that every particle of matter attracts every other particle of matter in a certain definite way. Galileo—as children say in the game of Hide-and-Seek—is very hot in respect to this doctrine. But he does not seem, at least in this passage, to have made the final generalization. He is thinking particularly of the Earth, the Sun, the Moon, and other planets—and his guardian angel does not appear to have whispered to him the generalization 'any material body'. Newton probably knew Galileo's Dialogues nearly by heart. They were standard works in his time. Cannot we imagine him sitting in his rooms between the gateway and the chapel of Trinity College, or in the orchard watching the apple fall, and with this passage of Galileo's Dialogue running in his mind, perhaps the very words of Salusbury's translation which I have quoted, 'the consentaneous conspiration of all the parts of the Earth to form its whole'. Suddenly the idea flashes on him—'What are the Earth and the Sun and the Moon? Why, they are any bodies! We should say therefore that any bodies attract. But if this be the case, the Earth and the Sun and the Moon attract each other, and we have the cause maintaining the planets in their orbits.' In this course of thought Newton would have been assisted by his third law of motion. For by it if the Earth attracts the apple, then the apple attracts the Earth.

By this conjectural reconstruction of Newton's state of mind we see that, given a genius with adequate

mathematical faculties, Newton's Principia is the next step in science after Galileo's Dialogues. Probably Galileo himself would have gone farther in this direction if his imagination had not been hampered by the necessity of arguing with the Conservative Party. It is in general a mistake to waste time in discussions with people who have the wrong ideas in their heads. But in Galileo's time and country the Conservative Party had thumb-screws at its service and could thereby enforce a certain amount of attention to its ideas.

Undoubtedly the whole implication of the answer of Salviatus is that the Earth, Sun, &c., are mere bits of matter. It is difficult for us to estimate how great an advance Galileo made in adumbrating this position. Consider for example this statement by Simplicius, made in another connexion, enforcing a doctrine which he upholds throughout the whole of the Dialogues:

> See here for a beginning, two most convincing arguments to demonstrate the Earth to be most different from the Cœlestial bodies. First, the bodies that are generable, corruptible, alterable, &c., are quite different from those that are ingenerable, incorruptible, unalterable, &c. But the Earth is generable, corruptible, alterable, &c., and the Cœlestial bodies ingenerable, incorruptible, unalterable, &c. Therefore the Earth is quite different from the Cœlestial bodies.

That is the sort of thing that Galileo was up against, not as a mere casual idea occurring to a subtle reasoner, but as the very texture of current notions. The primary achievement of the first physical synthesis was to clear all this away. Galileo with his telescope, his trenchant, bold intellect, and his magnificent physical intuition was the man who did it.

But we have not nearly exhausted Galileo's contributions to the general ideas of science. We owe to Galileo the First Law of Motion. Probably most of us

have in our minds Newton's enunciation of this law, 'Every body continues in its state of rest or of uniform motion in a straight line except so far as it is compelled by impressed force to change that state.' This is the first article of the creed of science; and like the Church's creeds it is more than a mere statement of belief: it is a paean of triumph over defeated heretics. It should be set to music and chanted in the halls of Universities. The defeated adversaries are the Aristotelians who for two thousand years imposed on Dynamics the search for a physical cause of motion, whereas the true doctrine conceives uniform motion in a straight line as a state in which every body will naturally continue except so far as it is compelled by impressed force to change that state. Accordingly in Dynamics we search for a cause of the change of motion, namely either a change in respect to speed or a change in respect to direction of motion. For example, an Aristotelian investigating the motion of the planets in their orbits would seek for tangential forces to keep the planets moving; but a follower of Galileo seeks for normal forces to deflect the direction of motion along the curved orbit. This is why Newton, at the moment which we pictured him as he sat in his rooms in Trinity College thinking about gravitation, at once saw that the attraction of the Sun was the required force. It was nearly normal to the orbits of the planets. Here again we see how immediately Newton's physical ideas follow from those of Galileo. One genius completes the work of the other.

It has been stated by Whewell that in his Dialogues on the Two Principal Systems of the World Galileo does not enunciate the first law of motion, and that it only appears in his subsequent Dialogues on Mechanics. This may be formally true so far as a neat decisive statement is concerned. But in essence the first law of motion is

presupposed in the argumentation of the earlier dialogues. The whole explanation why loose things are not left behind as the Earth moves depends upon it.

Galileo also prepared the way for Newton's final enunciation of the Laws of Motion by his masterly investigation of the uniform acceleration of falling bodies on the Earth's surface and his demonstration that this acceleration is independent of the relative weights of the bodies, except so far as extraneous retarding forces are concerned. He swept away the old classification of natural and violent motions as founded on trivial unessential differences, and left the way entirely open for Newton's final generalizations. Newton conceived explicitly the idea of a neutral absolute space within which all motion is to be construed, and of mass as a permanent intrinsic physical quantity associated with matter, unalterable except by the destruction of matter. He phrased this concept in the definition, mass is quantity of matter. He then conceived the true measure of force as being the product of the mass of the body into its rate of change of velocity. The importance of this conception lies in the fact that force as thus conceived is found to depend on simple physical conditions, such as mass, electric and magnetic charges, electric currents, and distances. We owe to Newton the final formulation of the basic physical ideas which have served science so well during these last two centuries. They comprise the foundations of the science of Dynamics, and Law of Gravitation. We also owe to Galileo's experimental genius the telescope and its first systematic use in science, the pendulum clock (subsequently perfected by Huyghens) and the experimental demonstration of the laws of falling bodies. To Newton's mathematical genius we owe the deduction of the properties of the planetary orbits from dynamical principles. To Galileo and Newton

we must add the name of Kepler so far as astronomy is concerned, and of Stevinus of Bruges so far as mechanics is concerned. He discovered the famous triangle of forces. But in one lecture lasting one hour you will not expect me to give a detailed account of the science of the seventeenth century.

In like manner we must add the name of Huyghens in mentioning the services of Galileo and Newton to the science of Optics. Huyghens first suggested the undulatory theory of light, to be revived at the beginning of the nineteenth century by Thomas Young and Fresnel. But the immediately fruitful work was due to Galileo with his studies on the theory of the telescope, and to Newton with his studies on the theory of colour. Both Dynamics and Optics reached Galileo as a series of detached truths (or falsehoods) loosely connected. After the work of Galileo and Newton they emerged as well-knit sciences on firm foundations.

Galileo's preoccupation with Optics doubtless helped him to another great idea which has coloured all modern thought. Light is transmitted through space from its origin by paths which may be devious and broken. What you see depends on the light as it enters your eye. You may see a green leaf behind the looking-glass; but the leaf is really behind your head and you are really looking at its image in the mirror. Thus the green which you see is not the property of the leaf, but it is the result of the stimulation of the nerves of the retina by the light which enters the eye. These considerations led Descartes and Locke to elaborate the idea of external nature consisting of matter moving in space and with merely primary qualities. These primary qualities are its shape, its degree of hardness and cohesiveness, its massiveness, and its attractive effects and its resilience. Our perceptions of nature such as colour, sound, taste and

smell, and sensations of heat and cold form the secondary qualities. These secondary qualities are merely mental projections which are the result of the stimulation of the brain by the appropriate nerves. Such in outline is the famous theory of primary and secondary qualities in the form in which it has held the field during the modern period of science. It has been of essential service in directing scientific investigation into fruitful fields both of physics and physiology. Now the credit for its first sketch is due to Galileo. Here is an extract from Galileo's work, *Il Saggiatore*, published in 1624. I take it from the English life of Galileo by J. J. Fahie[1]: 'I have now only to fulfil my promise of declaring my opinions on the proposition that motion is the cause of heat, and to explain in what manner it appears to me that it may be true. But I must first make some remarks on that which we call heat, since I strongly suspect that a notion of it prevails which is very remote from the truth; for it is believed that there is a true accident, affection, or quality, really inherent in the substance by which we feel ourselves heated. This much I have to say, that as soon as I form a conception of a material or corporeal substance, I simultaneously feel the necessity of conceiving that it has boundaries, and is of some shape or other; that relatively to others it is great or small; that it is in this or that place, in this or that time; that it is in motion or at rest; that it touches, or does not touch another body; that it is unique, rare, or common; nor can I, by any act of imagination, disjoin it from these qualities; but I do not find myself absolutely compelled to apprehend it as necessarily accompanied by such conditions as that it must be white or red, bitter or sweet, sonorous or silent, smelling sweetly or disagreeably; and if the senses had not pointed out these qualities,

[1] Published by Murray, London, 1903.

it is probable that language and imagination alone could never have arrived at them. Therefore I am inclined to think that these tastes, smells, colours, &c., with regard to the object in which they appear to reside, are nothing more than mere names, and exist only in the sensitive body; insomuch that when the living creature is removed, all these qualities are carried off and annihilated; although we have imposed particular names upon them (different from those other and real accidents), and would fain persuade ourselves that they truly and in fact exist. But I do not believe that there exists anything in external bodies for exciting tastes, smells and sounds, but size, shape, quantity, and motion, swift or slow; and if ears, tongues, and noses were removed, I am of opinion that shape, quantity, and motion would remain, but there would be an end of smells, tastes, and sounds, which, abstractedly from the living creature, I take to be mere words.'

If we knew nothing else about Galileo except that in the October of the year 1623 he published this extract, we should know for certain that a man of the highest philosophic genius then existed. On the subject of this extract, he leaves nothing for Descartes and Locke to do, except to repeat his statement in their own language, and to emphasize its philosophic importance. Indeed in many ways this original statement by Galileo is, as I believe, more accurately and carefully drawn than the usual formulations of modern times which I followed in my introductory remark.

I will now quit the special consideration of Galileo and Newton. I hope that I have with sufficient clearness given my reasons for holding that they are to be considered as the parents of modern science and as the joint authors of the first physical synthesis. You cannot disentangle their work. There would have been no Newton without Galileo; and it is hardly a paradox to

say, that there would have been no Galileo without Newton. Galileo was the Julius Caesar and Newton the Augustus Caesar of the empire of science.

But these men did not work in a vacuum. It was an age of ferment, and they had as contemporaries men with genius all but equal to theirs. Francis Bacon was a contemporary of Galileo, somewhat older (1561–1626). I need not remind you that Bacon was the apostle of the experimental method. He especially emphasized the importance of keeping our minds open throughout a careful and prolonged examination of the facts. Like all apostles he somewhat exaggerated his message, and perhaps undervalued the importance of provisional theories. But the main point is perfectly correct and particularly important in view of the tradition of the preceding 1500 years, during which experiment had languished. Aristotle had discovered the importance of classification, and neither he nor his followers had realized the danger of classification proceeding on slight and trivial grounds. The greatest curse to the progress of science is a hasty classification based on trivialities. An example of what I mean is Aristotle's classification of motions into violent and natural. Bacon's writings were a continual protest against this pitfall. Again the active life of Descartes lies between those of Galileo and Newton. He published his *Principia Philosophiae* in 1644, just two years after the date which I have assigned as the symbolic centre of the epoch. The general concepts of space and matter, body and spirit, as they have permeated the scientific world, are largely in accordance with the way in which he fashioned them. He viewed space as a property of matter and therefore rejected the idea of purely empty space. This conception of space as an essential plenum led him to speculate on the other physical characteristics of the stuff whose extension is space. He thus hit on the idea of the vortices which

carry along the heavenly bodies. These vortices are a failure. For one thing, they show that Descartes had not really assimilated the full import of Galileo's work in his discovery of the first law of motion. The planets do not want anything to carry them along, and that is just what Descartes provides. But for all that I hold that Descartes with his plenum was groping towards a very important truth which I will endeavour to explain before I finish this lecture. Newton's formulation of gravitation led Newton's followers to insist on the possibility of a vacuum, but the nineteenth century again filled space with an ether. Finally Einstein has recurred to the inversion of Descartes' doctrine and has made matter a property of space. The Newtonian vacuum and the Cartesian plenum have fought a very equal duel during the last few centuries. Leibniz, Newton's contemporary, emphasized the relativity of space.

This mention of relativity leads me to my last topic, which is to ask, how to-day we would criticize this First Physical Synthesis which we owe to the seventeenth century.

In the first place, if we are wise, before criticizing it we will stop to admire it, and to note its essential services to science, and (in its main outlines) its continuing value to-day. We must do honour to the century of genius to which we owe it—a century which will compare with the greatest that Greece can show.

By a criticism of the great physical synthesis which is the legacy of this century to science I do not mean a mere enumeration of the additions since made, for example, the rise of the concept of energy, of the atomic theory, or of the theory of various chemical elements. Such homogeneous additions leave the concept undisturbed. In this way, Kelvin made it the mainspring of all his scientific speculations. But for the last thirty years or

so, the great ideas of the seventeenth century have, so to speak, been losing their dominating grip on physical science.

Clerk-Maxwell probably thought that he had finally established its ascendancy. In truth, he had set going trains of thought which in the hands of his followers have caused it to totter. Galileo and his followers thought in terms of time, space, and matter. They were in fact more Aristotelian than they knew—though they wore their Aristotle with a difference. Clerk-Maxwell emphasized the importance of the electromagnetic field as an interplay of relations between various electromagnetic quantities. Maxwell himself looked on this field as merely expressing strains, stresses, and motions of the ether, a point of view quite in the Galilean tradition. But recently the field itself has come to be conceived as the ultimate fact, and properties of matter have been explained in terms of it. Thus energy, mass, matter, chemical elements are now expressed as electromagnetic phenomena. The ether is still there for those who like it, but it merely serves to allay the tortures of a metaphysical craving.

But Einstein and Minkowski have gone farther. Hitherto time and space have been treated as separate and independent factors in the scheme of things. They have combined them. This is a complete refashioning of older ideas and is in many ways much more consonant with the Cartesian point of view.

The world as we observe it involves process and extension. Hitherto process has been identified with serial time, and extension with space. But this neglects the fact that there is an extension of time. Conceive any ultimate concrete fact as an extended process. If you have lost process or lost extension, you know that you are dealing with abstraction. What is going on here in this room is extended process. Extension and process are each

abstractions. But these abstractions can be made in different ways. The space which we apprehend as extension without process and the time which we apprehend as serial process without spatial extension are not each unique. In different circumstances we affix different meanings to the notion of space, and different meanings to the correlative notion of time. In respect to space there is no paradox in this assertion. For us the space of this room is a definite volume; for a man in the sun the room is sweeping through space. But it is paradoxical to hold that the serial process which we apprehend as time is different from the serial process which the man in the sun apprehends as time. Yet if you do that, you can introduce mathematical formulae expressing spatio-temporal measurements which at one sweep explain a whole multitude of perplexing scientific observation. In fact the formulae practically have to be admitted, and the theory is the simplest explanation of them. Also philosophically the closer association of time and space is a great advantage.

We now come back to Descartes. He conceived extension as essentially a quality of matter. Generalize his idea: the ultimate fact is not static matter but the flux of physical existence: call any part of this flux, with all its fullness of content and happening, an event: extension is essentially a quality of events and so is process. But the becomingness of nature is not to be constricted within one serial linear procession of time. It requires an indefinite number of such processions to express the complete vision.

If this line of thought, which is that underlying the modern relativity, be admitted, the whole synthesis of the seventeenth century has to be recast. Its Time, its Space, and its Matter are in the melting-pot—and there we must leave them.

VII

SCIENCE IN THE INDUSTRIAL REVOLUTION

CECIL H. DESCH

To study the share of science in bringing about the great social change towards the end of the eighteenth century that we know as the Industrial Revolution is to turn from a time when science was the concern of a few intellectual leaders, and occasionally the amusement of a group of amateurs, to one when it came to affect the life of every member, even the least instructed, of the Western communities. It is to turn from isolated experiments in the harnessing of the forces of Nature to man's needs to a deliberate conquest and exploitation of those forces in the service of industry. We may observe the distinction that has been drawn between the industrial and the mechanical revolution, closely connected in history though they are. There is much evidence to show that the transition from domestic workshops to factories, and from small-scale handicrafts to capitalist production, was in course of taking place independently of machines, but the whole movement was hastened and intensified to a most remarkable extent by the new mastery of nature that came with the introduction of coal as a metallurgical fuel and with the invention of the steam engine. These two great inventions led to a complete transformation of industry. Not only was its character radically changed, but the distribution of population was altered by the establishment of the growing industries on the coal fields, ignoring previous historical conditions,

so that new centres of dense population grew up, hastily and without forethought, presenting those undesirable features that we commonly associate with the idea of the industrial revolution. For the moment we have only to deal with the main outlines of that transformation, attempting to relate it to the progress of science.

We should be wrong to suppose that organized industry on a large scale was a new thing in the history of the world. The canal system of Babylonia, the pyramids of Egypt, the great aqueducts of Roman cities, were achievements in construction comparable with any but the greatest works of modern times, demanding not only a vast supply of human labour, which the institution of slavery made possible, but a high degree of engineering knowledge and skill. It is difficult to picture the task of the ancient engineer, with primitive surveying instruments, cumbrous methods of calculation, and only the rudest of mechanical appliances for handling large masses of material. Nevertheless, the results achieved were marvellous, and modern engineers are beginning to study, with renewed interest, the methods adopted by their predecessors of Egypt and Rome. Neither was their work purely empirical. The ancient studies of geometry and physics were originally directed to practical ends, and some of the most important ancient discoveries in abstract science arose from attempts to solve the urgent practical problems of the land surveyor and the engineer. Simple mechanical devices which form the basis of elaborate mechanisms, such as the wheel and the lever, were known and commonly applied, whilst the labours of Archimedes and others had established the quantitative laws of some of them, notably of the lever. At a later date, the sea defences of Venice and Holland, which made it possible for those states to rise to power and commercial importance in spite of geographically unfavourable con-

ditions, may be named along with the great engineering works of Rome. We may place the Pyramids, as royal tombs, in a class apart, but all the other structures named had the character of public works, carried out under the authority of states or cities for the benefit of the general body of citizens. The mediaeval cathedrals are a most wonderful example of such co-operative work on a large scale, combining majesty of conception, skill in constructional design, and resourcefulness in overcoming technical difficulties. It was not new for large numbers of men to work together on a single task, or to employ mechanical appliances for the purpose, but it was new for goods for the market to be produced in this way. Capitalism was not new; contractors were often responsible for the undertaking of those great works of ancient times, and certain industries, such as iron smelting, were capitalistic in their organization from early times, but the production of ordinary goods in quantity for private profit was, with some exceptions, unknown before the eighteenth century. At that time, the textile industries and a few others started their new career, to be hastened almost inconceivably in their transformation before the century was out by the application of improved machines and more efficient mechanical power.

The spirit of invention, again, which seems to us so typical of the industrial revolution, was no new thing in human history. Among the Greeks, such legends as that of Daedalus commemorate the inventors of new crafts, of casting and hammering metals, of erecting buildings, and of constructing military engines. Hero of Alexandria, with his primitive steam engine and other scientific toys, as well as his serious military devices, is a witness to the existence of the capacity for designing elaborate mechanisms in the first century A. D., and Vitruvius, in the same century, in his descriptions of cranes and machines, now

and then seems oddly to anticipate modern inventions, as when he describes a taxicab, the distance travelled by a chariot being measured by the number of balls dropped into a bowl, each ball being released after a certain number of revolutions of the wheels. To come to later times, Leonardo da Vinci, one of the most marvellous men of genius in history, was a most fertile inventor, and his note-books, most of which have only become known recently, contain sketches and designs of machines for the most varied purposes. I need only mention a machine for cutting the teeth of files, an operation even now largely performed by hand. Many inventors, from Hero to Vaucanson, busied themselves with the construction of ingenious automata, imitating the action of men or animals, some of them exhibiting a high degree of manual skill and fertility of invention.

None of these inventions had any appreciable influence on industry. In looking for an explanation of this, we may note that, with the exception of Leonardo da Vinci, who was far in advance of his time, so that his projects could not be carried out until industry had made much further progress, inventors had confined themselves to two main classes of objects. Either their machines were built up of timbers, with at most small connecting parts of metal, like the military engines, storming towers and catapults of the ancients, or the water wheels of mediaeval industry, or they were delicate mechanisms, like the automata of Vaucanson, calling for ingenuity and dexterity, but making no severe demands on the strength or quality of the materials used in them. Machines of the modern kind only become possible when the art of working large masses of metal has reached a high state of development. Broadly speaking, this was not the case before the latter part of the eighteenth century. There have been exceptions: the ancient Indian iron forgings,

although they were limited to pillars and simple beams, still excite our admiration, and the art of casting bronze for statuary arrived at extraordinary perfection even in early Greek times, and was preserved and perfected by the great German and Italian masters of the Renaissance, as Peter Vischer of Nuremberg and Benvenuto Cellini. The casting of iron was limited to comparatively small masses, cannon being the largest, and forging to still smaller masses, such as could be dealt with by a tilt hammer worked by water power. The metallurgical revolution had to precede the mechanical, and it was not until iron could be handled in quantity with ease and certainty that a machine, however ingenious, had a chance of becoming a practical success.

The smelting of iron had been performed from prehistoric times in a simple manner, by heating the ore with charcoal in a primitive furnace, urged to a sufficiently high temperature by a blast, the bellows being driven by hand or later by water power. With only slight modifications, this process persisted for many centuries. It was only suitable for pure ores and for small quantities, and the special skill required for the operation combined with certain elements in social tradition to place the smith in a place apart, as is shown by legends and folk-tales in many countries. From the time of the Romans onwards, the process was improved by almost imperceptible steps, due to inventors of whom we know next to nothing. The most that we can do is to trace, partly in documents but chiefly in such material remains as the destructive action of time has left to us, the passage of a new metallurgical process across Europe. Some of the most important improvements in the smelting of iron probably came to us from the Walloon country in the east of Belgium. A few men of real scientific ability devoted themselves to the study of metals, chief amongst them being Georg

Bauer or Agricola, to whom we owe a magnificent treatise, published in 1556, in which we have clearly set forth the processes of mining and smelting then in use, with such scientific explanations as were then possible. Agricola is wonderfully modern in his outlook, and his rejection of alchemy and of all far-fetched theories of the origin of minerals in itself entitles him to an honourable place in the history of science. For a complete understanding of metallurgical processes a knowledge of chemistry is necessary, so that a truly scientific control of the industry was not possible until much later.

To fix our ideas, we may consider the state of the English iron industry in the latter part of the sixteenth century. The principal region was the Weald, most of the works lying in Sussex, with extensions into Surrey and Kent. Here blast furnaces, worked by means of charcoal, made the cast iron, and when malleable material was wanted, the same fuel was used for the conversion. Water power was necessary to blow the furnaces and to drive the forging hammers. The consumption of wood for charcoal was large, so that even in 1558 a statute was passed to prevent the destruction of forests for this purpose. At first Sussex was exempted, but later the prohibition was extended, and the movement of the industry to the Forest of Dean, another old smelting centre, took place. There was a constant strife between the claims of the State, which required timber especially for shipbuilding purposes, and the needs of the growing iron industry. By the beginning of the eighteenth century the scarcity of wood in England was so serious that the ironmasters of the Furness district of Cumberland were erecting works in the Scottish Highlands, where timber was still to be found and the restrictions did not apply.

In the face of these difficulties, it is not surprising that attempts were made to replace charcoal by coal, already

long a familiar domestic fuel. Dud Dudley, in the middle of the seventeenth century, was the most successful of these experimenters, but the jealousy of his rivals put an end to his work, and it was not until 1757 that coal, previously converted into coke, was successfully used in blast furnaces at Coalbrookedale in Shropshire, where also the first cast-iron bridge and the first iron rails for mine trams, in place of wood, were used. This change marks a turning-point in industrial history. The greater cheapness and facility of coal made the manufacture of iron (steel was still only made on a very small scale) possible, and thus began the migration of industry to the coal-fields, which has led to the present distribution of the population, so different from that of the era preceding coal. The time was now ripe for the mechanical revolution.

Mechanical power, for driving corn-mills and forge hammers, for blowing furnaces, and for grinding cutlery, had been hitherto derived from the wind or from the fall of water to a lower level. The wind is too variable to be applied widely, and windmills are only possible in flat countries; but water power has wide applications. We can imagine how a great industrial civilization might have grown up, organized for production on a large scale, and based on water power. The use of the water-wheel was common throughout Europe, and the extension would have been a natural one. The damming of streams to form 'hammer ponds', each supplying a wheel, was characteristic of iron-working districts, and the corn-mill has been a feature of agricultural life for centuries. But practical difficulties stood in the way of any such development. The very power of great waterfalls, such as the Falls of the Rhine at Schaffhausen, made it impossible to utilize them. The simple water-wheel, built up of timbers, however skilfully constructed, would have been

crushed by the mass of falling water, and all that man could do with such a source of power was to lead off some minute fraction through a channel to supply a single wheel. Only a modern turbine, scientifically designed to take the full force of the water, and constructed of materials of exceptional strength, can serve in such a case, and for that neither the knowledge nor the means existed. Had the invention of the water turbine preceded that of the steam engine, the geographical distribution of industry would have been far other than it is. The other great natural sources of power—the tides and the direct heat of the sun—have so far baffled even the engineers of our own day.

Thus, of the natural sources of power now known to us, there only remained the combustion of fuel. To convert the chemical energy of wood or coal into mechanical energy is not directly practicable, and the suggestion would never have occurred to an early inventor, since the very conception of energy, and of the mutual equivalence of different kinds of energy, did not arise until after the date of the industrial revolution. We may consider the scientific knowledge that was available in the period immediately before the invention of the steam engine. The laws of statics, the simplest of which had been established by Archimedes both for solids and for liquids, were extended by Stevin of Bruges and later by Galileo, who is also the true founder of dynamics. The great work of Newton had brought mechanics to such a state of perfection that the most difficult problems in connexion with bodies at rest or in motion could be solved, with the aid of the new mathematical methods due to Napier, Descartes, Newton, and Leibniz. The study of gases was of more recent origin. Ctesibius of Alexandria, the teacher of Hero, is credited with the first scientific studies of air and steam, and the expansive force of gases

was known to him, but it is with the work of Torricelli and Boyle that a firm foundation for a knowledge of the properties of gases, including steam, is first apparent. Boyle, one of the most brilliant of that group of men who established the Royal Society, and so gave practical form to the new creed of experiment as the true means of investigating Nature that was making its way in England, added more than any other man to our knowledge in this field. By discovering the relation between the volume of a gas and the pressure to which it was subjected, he made it possible to define quantitatively the behaviour of an enclosed volume of gas under different conditions.

The scientific knowledge required for the construction of a simple steam engine was in existence by the middle of the seventeenth century, but it was long before it was practically applied. Among the devices of Hero of Alexandria had been a machine, capable of performing simple motions, which depended on the expansion of air in a partly closed vessel, forcing water into another vessel, and it was this contrivance that formed the model for the earlier inventors. Della Porta in 1601 replaced air by steam, and suggested that the condensation of the steam might be utilized in drawing up water from below. De Caus and the Marquis of Worcester suggested similar machines, pumps rather than engines, intended for the lifting of water, but none of these ever assumed practical shape. It was not until 1698 that Thomas Savery made a working steam engine on this principle, involving several ingenious details, and finding direct application in the pumping of water from mines, a question then beginning to assume importance. As the metallurgical demand for coal increased, shallow workings became insufficient, and miners were prevented from working at greater depths by the accumulation of water in the

mines. Savery's engine worked with pressures sometimes as high as 8 or 10 atmospheres, and naturally gave much trouble from leakage. In principle it was not unlike the modern pulsometer pump.

Denis Papin in 1690 adopted an entirely different principle. The use of a piston moving in a cylinder was already familiar in the common suction pump, and Papin, by condensing steam in the lower part of the cylinder, caused the piston to descend by atmospheric pressure. Huygens had shortly before proposed an explosion engine with piston, a crude forerunner of the modern internal combustion engine. Neither had any practical consequences. Newcomen, in 1705, constructed a steam pumping engine which held the field for the greater part of the century. He used a piston, but made the boiler for generating steam a separate vessel from the cylinder, and brought about the condensation of the steam by admitting a jet of water. The piston rod moved one end of a beam, to the other end of which was attached the pump rod, and in this form, the movement of the necessary valves soon being made automatic by connecting them with the beam, the machine was long employed for raising water from mines. One is even now in use in the Sheffield district. Many of these engines were built at Coalbrookdale. Great strength was not required, as the pressure never differed greatly from that of the atmosphere.

So far the engines had all been examples of mechanical ingenuity, involving no new principles, and based only on the simplest mechanics. The next great step was not taken at random, but was the result of the application of new principles. James Watt was much more than a merely ingenious mechanic. Skilled workman as he was, he was the close friend of two active investigators in physics, Black and Robison, and with them and others

of like intellectual standing he discussed his inventions. Struck by the inefficiency and wastefulness of the Newcomen engine, he rightly saw that this came from the alternate heating and cooling of the cylinder. Black's discovery of latent heat had shown how large a quantity of heat is released when steam is condensed to water, and Watt, applying this knowledge, took the decisive step of separating the cylinder from the condensing vessel. This is not a memoir on the steam engine, and it is impossible to enter into the wonderful record of Watt as an inventor, adding detail after detail until the crude steam pump had been converted into an efficient engine, the reciprocating action of the piston being converted into rotary motion by means of the crank, so making it possible to employ the steam engine to drive machinery in a factory or, as was done later, to fix it into a boat for steam navigation, or on wheels as a locomotive. Subsequent developments, remarkable as they have been, are essentially matters of detail.

Before leaving this subject, a suggestion of Giovanni Branca in 1629 may be mentioned. This was to direct a jet of steam against the vanes of a wheel, and so produce rotation. This suggestion bore no fruit, but it is interesting in the light of recent mechanical history. Many inventors from time to time reverted to the idea of a steam turbine, but the plan proved to be unrealizable, The high speed of such an engine was a practical difficulty, whilst the principles were yet unknown. The theory of the heat engine, according to which the maximum efficiency of the most perfect engine is limited by the temperatures between which it works, was only established in 1824, by Sadi Carnot. Carnot showed that heat does work when it falls from a higher level (of temperature) to a lower, but that an equivalent quantity of heat disappears in the process was not realized until the

establishment of the doctrine of the conservation of energy in 1843 and succeeding years, by the labours of Joule, Mayer, and Helmholtz. It is this doctrine that controls the efforts of modern inventors, and makes immediately evident the absurdity of proposals to increase the amount of energy in a system without taking it from somewhere else. A lack of comprehension of this principle is responsible for many fallacious suggestions. The steam turbine is a quite modern invention, scarcely forty years old, and is based on a most thorough study of the properties of steam, as well as of those of metals used in its construction. It could never have been arrived at by a process of happy guessing, or of trial and error.

Watt's engine could not have been constructed at an earlier period. It was not a pump, but an engine in the modern sense, and required not only relatively large masses of metal, but accurate casting and boring, things that could not yet be obtained. On reading the life of Watt, one is struck by the great practical obstacles that confronted him at every stage. Although his early engines were atmospheric, depending on the vacuum produced by condensing the steam for their action, so that high pressures were unnecessary, his cylinders had to be large to give sufficient power, and even when the casting difficulties had been overcome there was the difficulty of boring the cylinder so that the piston would make a reasonably tight fit. Gradually, Watt and his associates triumphed over their difficulties, and after many years of effort and discouragement the steam engine became the agent of the mechanical revolution. The same metallurgical advances that had created the demand for engines for pumping, on account of their large consumption of coal, made it possible for the engines to be constructed. The Carron works in Scotland, with which

Watt was associated through Roebuck, assisted him in the manufacture of them as well as by making use of them when made.

In the meantime a revolution in the manufacture of textile materials had been going on in this country. Hargreaves, Arkwright, and Crompton had invented machines, depending on no new principle, but ingeniously combining simple mechanical movements, which could replace hand labour and allow of the production of textile fabrics on an enormously increased scale. Whilst the machines were at first driven by water power, and the mills were therefore placed near to streams having a sufficient fall, the usefulness of steam power for the purpose was soon obvious, and in 1785 the first steam cotton mill was set to work in Nottingham.

Factory production on a large scale was first adopted in the metal industry. The iron and steel works of Abraham Crowley at Newcastle employed several hundred men in 1682. There had been textile capitalists employing as many persons much earlier, but their workers were scattered through small domestic workshops, and not collected into a single factory. With the invention of power machinery for spinning and weaving textiles came the organization of that industry also on a factory plan, and the engineering industry followed as a consequence. The change having once set in proceeded with ever-increasing velocity, until the present conditions of industry were reached. In the great majority of manufactures, machine production has superseded hand work, whilst the immense developments of mechanical transport have transformed the conditions of industrial life throughout.

Not all industries were affected to an equal extent. As we have seen, the invention and construction of the steam engine and of the machinery for textiles demanded

knowledge which was supplied by the sciences of mechanics and physics, already sufficiently advanced by the middle of the eighteenth century. Scientific chemistry is only considered to date from the time of Lavoisier, so that the transformation of the chemical industries, formerly exceedingly primitive, came much later, and in fact is only now in progress. Agriculture was improved, but for any radical transformation a scientific knowledge of biology was needed, and that is of quite modern growth. We are still only perceiving the firstfruits of the systematic application of biological science to agriculture, a reformation which may well transform rural life, and to some extent counteract the evil influences of the industrial revolution.

Those evils were immense. The introduction of steam power almost immediately opened the way to the rapid and cheap production of many classes of goods. It was found that large profits could be made by employing labour in great factories. Competition became intense, and to secure a remunerative share of any manufacture the costs of production had to be kept as low as possible, hence the misery and cruelty of the late eighteenth and early nineteenth centuries. Unfortunately, the growth of facilities for manufacture was far too rapid for the essential social readjustments to keep pace with it, and evils accumulated fast. Moreover, the new discoveries came at a time when the moral sense, in this country at least, was of a low standard. Even admirers of the eighteenth century must admit that a selfish complacency was characteristic of much of its life, and that the influence of religion on morality was then at its lowest ebb. It may seem a paradox that the Methodist movement and the Evangelical revival did practically nothing to counteract the selfishness of the new industrial era. It is remarkable that even Hannah More, in her accounts of her

endeavours to promote a knowledge of the Bible among the poor, scarcely betrays a suspicion that the condition of the industry of her time, with its appalling misery for a large proportion of the workers, was anything but a natural and inevitable state of affairs, and her complacent reflections on the good fortune of the rich are to a modern reader strangely heartless. The fact is that the new religious fervour was so directly and intensely concerned with a future life that its influence in improving the conditions of this world was almost insignificant. A curious narrowness is perceptible in the attitude of some even of the most earnest of religious philanthropists at a somewhat later date. The leaders of the movement for the abolition of the slave trade, with a few honourable exceptions, took little notice of the virtual slavery and misery of the industrial population of our own country. The influence of the churches and the sects was small, and when the means of acquiring wealth rapidly presented themselves, there was no restraining force of adequate strength to oppose the greed of the new industrial chiefs. Dickens's Mr. Gradgrind, although later in date, is a typical figure of the age. Suitably controlled, we can picture a mechanical revolution which would have rendered life infinitely happier, by improving comfort and lessening toil, without imposing a practical slavery on large masses of workers, or converting great tracts of beautiful country into hideous wildernesses, as has been the case in the north. Mr. Austin Freeman has made a good point in remarking that the introduction of machinery, whilst it has destroyed many handicrafts and turned many classes of skilled craftsmen into soulless machines, has done but little to remove the drudgery of everyday life, so that men are still employed in the roughest of mechanical tasks that might well be performed by machines, and the housewife has derived little

benefit in her daily toil from all the inventions of the mechanical age. This is true, and whilst it emphasizes some of the lessons preached so eloquently and so fruitlessly by Ruskin, it points a way to possible reforms in the future.

One of the worst features of the industrial revolution is the wasteful treatment of natural resources. In the first enthusiasm of the discovery of steam power, it seemed that Nature had placed in the hands of Man an inexhaustible source of wealth. Coal was abundant in England, and the idea of its possible exhaustion did not present itself to the minds of those who used it. Whole counties were laid waste in order that goods might be produced cheaply, whilst smoke and slag heaps were allowed to disfigure the country. Professor Geddes has rightly said that the industrial age must be divided into two, a Palaeotechnic and a Neotechnic Age, in the first of which natural resources were squandered and social good subordinated to private gain, whilst in the second those conditions are reversed. We are only now seeing the beginnings of the Neotechnic Age.

It would be wrong to blame science for the evils of industrialism. It was scientific discovery, misapplied in practice, that made those evils possible, but the spirit of industrial greed was not that of science. In another aspect, also, it was the imperfection of science that led to its misapplication. The waste of natural resources could hardly have been so great had the idea of the conservation of energy been present to men's minds. It was of later growth, and was not in time to prevent the evils. Even now it is so little comprehended by the ordinary man of business that his actions are hardly affected by it. Further, the scientific study of human physiology came too late to warn men of the consequences of the unhealthy conditions of industrial life, whilst the

fact that social science had not yet come into existence was the most potent of all in permitting such outrages on social good as characterized the system. Science, that is, the mechanics and physics of the time of Watt, might have been used to increase the sum of human happiness, and it is not the fault of science that it was not so used. Science is not responsible for its misuse by selfish men. In the last few years the cry has again been raised that materialistic science is responsible for the horrors of war, because chemistry and physics have been applied to the production of more destructive and crueller means of warfare. The danger of such misapplication still exists, and has to be reckoned with. One of the great aims of physical science of the present day is to discover a means of tapping the vast store of energy contained within the atom, and revealed to us by the phenomena of radioactivity. As Professor Soddy, one of the leading workers in that field, has remarked, the first application of that discovery, should it be made, would undoubtedly be the invention of a bomb, incomparably more destructive than any hitherto known. This is a real danger, but it cannot be allowed to hinder scientific investigation. The same discovery might be used to alleviate the hardships of life and to bring about a happier social state, and we must look to the control and not to the suppression of invention for a remedy for the evils of misapplied science.

At the same time as the discoveries in mechanics and in the properties of gases, a new force was being studied, the knowledge of which was not to bear fruit until much later. It was in the year 1600 that William Gilbert, a court physician to Queen Elizabeth, published his treatise on the Magnet, in which for the first time experiments on electricity and magnetism were carefully described. This great work laid the foundation of a new

science, but for more than two centuries that science grew slowly, and even the brilliant discoveries of Franklin, Cavendish, and Volta had no immediate practical consequences for industry. The discoveries of Oersted and Ampère led to the invention of the electric telegraph; but it was not until Faraday, one of the greatest experimenters in the whole history of science, established the principal laws of electromagnetism, that industrial applications of electricity became possible. The dynamo and the electric motor, with their more recent companion, the electric furnace, are the instruments of a new mechanical revolution taking place before our eyes, but of which only our descendants will see the full results. Electrical power will be the chief practical means of bringing about the change from the palaeotechnic to the neotechnic age. One feature of its influence is to be remarked in the geographical redistribution of industries, especially in the transference of some of them from the coal-fields to the mountainous regions where water power is abundant, with the attendant possibility of making a fresh start, untrammelled by the surroundings of a palaeotechnic industrial region.

We may note in passing, although it belongs to a later period than that of the introduction of the steam engine, that electrical invention has pursued a rather different course from mechanical invention. Whilst the design of new mechanical devices has often been instinctive or based merely on a process of trial and error, the underlying scientific principles being established later—the steam engine was a practical success before the theory of heat engines was worked out by Carnot—the practical applications of electricity have followed on the theory Wireless telegraphy was not the result of a happy guess or of a process of trial and error, but was a direct application of a theoretical prediction of Clerk-Maxwell, tested

experimentally by Hertz. The thermionic valve, which has made wireless telephony possible, is a consequence of purely scientific investigations on the emission of electrons from heated bodies—investigations apparently remote from any practical applications. Electrical inventions are historically more recent than mechanical, and it is probable that the course of their history will be the normal one in the future, invention following on theory instead of preceding it. The time has passed when a happy guess may result in an epoch-making discovery.

The growth of mechanical industry became more and more rapid as the years of the nineteenth century passed. Two factors in that growth may be selected for brief mention, the development of the manufacture of steel and the rise of the chemical industries. Whilst, in the period that has been considered, iron was made on a large scale in the blast furnace by the use of coke, such steel as was required was manufactured on a relatively small scale, Huntsman's crucible process of 1740 being used for the greater part of the production until the middle of the nineteenth century. Then two great inventions, that of Bessemer and that of Siemens and Martin, revolutionized the industry. The two were almost simultaneous, but the former sooner became a practical success. By blowing air through pig iron in a suitable vessel, a quantity of iron weighing several tons could be converted into steel in twenty minutes, and the scale of production increased almost immediately. From this point onwards the curve which shows the annual production of steel rises with increasing steepness until 1913. The Siemens-Martin, or open-hearth process, was slower in making its way, but is now in this country by far the more important, and is everywhere gaining ground on its rival. The world's production of steel, which was about 100,000 tons in 1848, was about 76,000,000 tons in 1913. These

vast quantities of cheap material have transformed the construction of buildings, bridges, and ships, and we now live in a veritable Steel Age. Metallurgical chemistry has added a wide range of alloy steels, containing nickel, chromium, tungsten, and other metals, to the materials available to the engineer, surpassing the older steel and iron in strength and elastic qualities, and so making possible the construction of the motor-car and the aeroplane.

The chemical industries are essentially of modern growth. The great alkali industry, the foundation of all the others, began with the invention of the Leblanc soda process in 1791, and soon found a home in England, where it flourished. Popular attention, however, has been more constantly directed towards that part of the chemical industry which deals with artificial dyes and drugs, the industry of coal-tar products. Scientific chemists having shown the presence of definite chemical compounds in the tar obtained in the distillation of coal, the first coloured compound, mauve, was prepared from it by Perkin in 1856, since when the industry has reached an extraordinary development, many thousands of compounds having been prepared, including a wide range of synthetic colouring matters and therapeutic agents, and of such minor but yet important substances as photographic developers. The virtual capture of the industry by Germany, owing to the employment of an army of chemical investigators by the manufacturers, has caused a widespread interest in its fortunes, its social and political importance being quite disproportionate to its magnitude, which is far below that of other branches of industry. The coal-tar products have formed the text of many a homily on the importance of scientific education, but it must not be forgotten that its lessons are equally applicable to many other industries, which can only flourish and grow when scientifically controlled.

Unfortunately, the manufacture of synthetic chemicals

involves more than the production of dyes and drugs. Modern high explosives belong to the same class and are derived from the same source, and whilst these, by their use in mining, have increased efficiency and diminished danger, they have made warfare more deadly and have enormously increased its scale. So, too, the knowledge of many compounds prepared in the laboratory and remarked for their noxious qualities led to the introduction in the great war of ' poison gases ', the last refinement of horror in fighting. These are among the misuses to which all scientific discoveries are liable to be put, as long as the general conscience is insufficiently powerful to control them.

Closely allied to explosives, however, are the artificial fertilisers by means of which the yield of cereals and other crops can be so largely increased. By combining the experience of the chemist with that of the electrician, means have been found of converting the nitrogen of the air into compounds which serve in time of peace to increase the fertility of the land, and in time of war to form the foundation of high explosives. Hence the importance of the synthetic nitrogen industry, which requires cheap electric power, derived from water, for its existence, and therefore tends to establish itself in new districts, on the coast of Norway, among the mountains of Central Europe, or on the shores of the Pacific. It is being followed by a number of other electrochemical industries, which associate themselves with it, and are assisting in that transfer of industry from the coalfields of which mention has already been made.

The early scenes of the industrial revolution were set in England, where both invention and application advanced more rapidly than elsewhere. For many years other nations were content to follow at an interval the path traced out by British industry. It was only later that they became serious rivals, and the struggle for

industrial supremacy belongs to a later period than that considered in this essay. There were several reasons for this industrial leadership of England. Her supremacy in shipping and in foreign trade had given the people an active interest in industrial production, and stable political conditions had favoured the growth of a large industrial population, including many skilled craftsmen. When the change in the manufacture of iron took place, coal, ironstone, and fireclay were found together in abundance in the north, giving this country a great natural advantage at the start. It is remarkable how, as each successive development arose, suitable raw materials were found conveniently placed—clay for steel crucibles, ganister for the Bessemer process, and so on.

But these material factors are not sufficient in themselves to account for the English leadership in the industrial revolution. There was a practical bias of the English intellect that also played its part. The experimental method of investigation, although splendidly represented in Italy by Leonardo da Vinci and Galileo, is most characteristic of English science, from Roger Bacon onwards. It is commonly associated with his later namesake, but the name of Francis Bacon was rather a rallying cry for the school than anything more. The strict Baconian method, as expounded in detail by its author, was barren of results, although the general principle was an inspiration, and the real founders of the experimental school were Boyle and the men who established the Royal Society. They fought under the banner of Bacon, but their methods were their own, and it was their work, interpreted by Voltaire and d'Alembert, that influenced Continental science. The philosophy of Locke had a practical tendency, and whilst French speculative thought in the eighteenth century took mainly a political direction, that of England was essentially practical.

That the advocates of experimental investigation looked

deliberately to industrial applications of their discoveries may be made clear by quoting a passage from Bishop Thomas Sprat's *History of the Royal Society*, published in 1667. Sprat was one of the founders of the Society, and his essay is a powerful defence of the experimental method against criticisms from the philosophical and religious points of view. After showing how inventions have mostly arisen from one of three causes—chance, the desire of pleasure or luxury, and necessity—he goes on to show that the study of experimental philosophy, as he calls it, provides a more excellent way:

> It is impossible for us to administer this *power* [of dominion over nature] aright, unless we prefer the light of men of *Knowledge*, to be a constant overseer, and director, of the *industry*, and *Works* of those that labor. The Benefits are vast, that will appear upon this conjunction. By this means the *Inventions* of *chance* will be spread into all their various uses, and multiply'd into many new advantages: By this the *Productions* of *necessity*, will be amplify'd, and compleated: By this those of *Luxury*, and *Wantoness* may be reduc'd to some solid ends: By this may be rays'd almost as certain a Method to invent new *Mechanics*, as now any particular *Mechanics* can practise, to produce their own *Operations*. . . . By this that will be amended, which has bin hitherto the misfortune of such *Inventions*, that they have commonly fallen into mens hands, who understood not their *Natures*, *uses*, or *improvements*: By this the conceptions of men of *Knowledge*, which are wont to soar too high, will be made to descend into the *material World*: And the flegmatick imaginations of men of *Trade*, which use to grovell too much on the ground, will be exalted.

We have seen that the industrial revolution was the consequence of the new movements in science and philosophy. Without the discoveries in mechanics and physics of the seventeenth century, the methods of industry could not have been transformed in the eighteenth. That the social consequences of the change were in

large measure disastrous, and that a period of callous cruelty almost unexampled in history followed on an invention that might have brought material comfort to all, is to be attributed to the low standard of morality then prevailing, to a temporary retrograde movement in religion, and to the fact that the practical development of the physical sciences had outstripped the growth of abstract science. Biology was scarcely born, sociology had hardly been dreamed of as a science. In the great transition that is before us, from the selfish, wasteful, and ugly Palaeotechnic age to the peaceful organization of Neotechnic industry, all the sciences will have to take their part. Some of the most ardent advocates of the claims of science to be the guide of national and social life are apt to restrict the scope of science too narrowly, including in it only the physical aspects of the universe, perhaps adding the study of the animal and vegetable world. Viewed so narrowly, science is dangerously open to misapplication in the cause of commercial interests or of military ambitions, and it is only when its scope is so extended as to include the life of man in society that the reproach can be avoided. The conception of science as a whole, ranging from mathematics to sociology and ethics, is the true safeguard against its misuse in anti-social ways.

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VIII

THE INFLUENCE OF DARWINISM ON THOUGHT AND LIFE

J. ARTHUR THOMSON

§ 1. *Meaning of Darwinism*

IT is useful to take 'Darwinism' in a large sense, as including six great ideas. *First*, there is the web of life, the inter-relations binding organisms together, the linkages which form an increasingly intricate system. Cats are connected with the clover crop and with the incidence of the plague in India; water wagtails have to do with the success of sheep-farming, and little fishes with malaria. No creature lives or dies to itself. There is correlation of organs in the body; there is correlation of *organisms* in Nature. *Second*, there is the struggle for existence, all the answers-back that living creatures make to environing difficulties and limitations, partly in competition with fellows of the same kith and kin, partly in parrying the attacks of foes belonging to other races, and partly in reaction against the callous fates of the physical world. The struggle may mean girding the loins or tightening the belt, trimming the lamps of the senses or quickening the pace, putting on a garment of invisibility or 'attending the mind thereunto', to use Sir Isaac Newton's phrase. *Third*, there is the idea of variability, the mysterious fountain of change which wells up from the germinal depths, sometimes resulting in a little more of this quality and a little less of that, sometimes leading to a remarkable shuffling of the hereditary cards so that the outcome is a distinct novelty.

Fourth, there is the idea of sifting or winnowing, the selection that the struggle for existence involves, a very varied and often subtle process, as Darwin always insisted. *Fifth*, there is included in Darwinism a vindication of the general idea of evolution, that the present is the child of the past and the parent of the future. This was indeed an old idea, but Darwin made it current intellectual coin. He showed that it was a formula that fitted—a modal, rather than a causal description of what had occurred. But Darwin proceeded to change it into a causal theory by showing how the consistent Natural Selection of variations might work out new adaptations. *Sixth*, we must include in Darwinism the thesis that Man is solidary with the rest of creation and the outcome of a process of natural evolution. Such then are the six great ideas included in Darwinism.

§ 2. *Changes in Darwinism*

The next question is more difficult: How has Darwinism changed since it was first promulgated? For of course it has made progress, and it is with the Darwinian body of doctrine that we have to deal, not with Darwin's *ipsissima verba*. It would indeed be a bad sign of an evolution theory if it did not itself evolve!

First of all, it may be said that the fact of evolution stands more firmly than ever; the uncertainties concern the *factors*. Perhaps it is clearer than it used to be that it does not *explain* anything to say that it evolved, for that is merely stating the manner of its becoming. Perhaps it is clearer than it used to be that there is no way of proving the evolution theory as one might prove the law of gravitation; all that can be shown is that it is a descriptive formula that fits, and that there is nothing to contradict it.

Apart from a few heretics who profess to believe—in

defiance of the rock-record—that the lower forms of life are derived by simplification from the higher, there is unanimity as to the derivation of our present-day fauna and flora from an antecedent fauna and flora on the whole simpler, and so on back and back. And apart from Professor Bateson's inquiry 'whether the course of Evolution can at all reasonably be represented as an unpacking of an original complex, which contained within itself the whole range of diversity which living things present', there is general belief in an age-long progression from the simple to the complex, a general increase in differentiation and integration, and a frequent emergence of what must be called new.

For a time naturalists spoke as if they knew everything about evolution; now it is rather the fashion to speak as if we knew nothing about it. The fact is that while our ignorance remains immense, as Darwin said, we have come to know a good deal. The general idea of organic evolution commends itself to all naturalists, and it is justified of its children. But it is not so easy as it looks. This is plain whenever we pass from the fact to the factors. If the inquiry were not very young there would be reason for being disappointed over the uncertainties that surround the problems of variation, heredity, and selection; and over our ignorance of the precise pedigree and mode of origin of the great types, such as Backboned Animals or Birds. We have not even attained to clearness in regard to the origin of a species—i.e. a discontinuous group of similar individuals, breeding true (in the main) *inter se*, but not readily fertile with other species.

§ 3. *Changes in regard to Variation*

For the raw materials of evolution, Darwin relied chiefly on minute fluctuations, the origin of which he confessed he did not know. He was intrigued by brusque

or saltatory variations, but he thought that they would be swamped by intercrossing. He inclined to a belief in some transmission of the direct organismal results of changes in environment, nutrition, use and disuse. In speaking of fortuitous variations he meant little more than that the particular combinations of causes that give rise to a new departure remain unknown. He had the idea that two or more different variations may be linked together or correlated, one involving the other.

We know now that variations are even more abundant than Darwin supposed. The fountain of change is often overflowing. We know what Darwin did not realize, that most of the variations—some would say *all*—are due to *germinal* permutations and combinations. We are very dubious in regard to the transmissibility of somatic modifications ('acquired characters') as such or in any representative degree; though it is premature to shut the Lamarckian door. We know that discontinuous variations or brusque mutations are common, and that they have great staying power in inheritance. In some cases it is certain that the germinal 'factors' corresponding to these mutations and to all or many of the discrete non-blending 'unit characters' of the organism lie in longitudinal order in the chromosomes of the nucleus of the germ-cell. In a few cases something is known of their topography. In the fruit-fly Drosophila there are known to be about 7,500 of these 'factors' or genes—hereditary cards which can be shuffled. One hereditary 'factor' or 'determiner' may affect several adult characters (corroborating Darwin's idea of the correlation of variations), and one adult character may be the outcome of several 'factors'.

There is strong palaeontological and some experimental evidence that variations are sometimes definite or orthogenetic, i.e. occurring consistently in a particular direction.

In other words, a variation may be congruent with what has already been enregistered in the organization of the creature. Just as an architect cannot add a random new feature to a building, but only what is consistent with the given style, so it is unlikely that 'anyhow' variations are common. The organism is a unity, even when it is an implicit organism, the germ-cell.

As to the origin of the new, we know much in regard to the opportunities afforded for shuffling the hereditary cards during the life-history of the germ-cells, especially during maturation and fertilization. There are some facts which show that deeply saturating environmental, nutritional, and functional peculiarities may pull the trigger of germinal changefulness. And just as there is a periodic scrapping and reorganization (endomixis) in the nuclear constitution of a slipper animalcule, artificially kept in a pure-line culture in which conjugation does not occur, so there may be spontaneous rearrangements and reorganizations in the complex nucleus of a germ-cell. What is particularly baffling is not the occurrence of a little more of this or a little more of that, but the emergence of something distinctively new. It looks as if the germ-cells made experiments in self-expression.

§ 4. *Changes in regard to Heredity*

Darwin was one of the first to show that heredity is amenable to scientific treatment. He had a particular theory of his own—an ingenious hypothesis of the centripetal passage of gemmules from changed parts of the body to the reproductive organs. In this way the changes hammered on to the individual body might conceivably affect the next generation. But Darwin had no clear idea of the continuity of the germ-plasm, and therefore did not understand the radical reason why like tends to beget like. That was made plain by his cousin Francis

Galton and by Weismann. Most unluckily Darwin did not come to know the work of Mendel, which would have delighted him. Thus he was unaware of the precise vehicles of the factors for hereditary characters (which are carried by the chromosomes of the nucleus of the germ-cells); and he did not know how those from the two sides of the house are sorted out among the offspring in intelligible proportions. What we do not know is how these 'factors' come to be, how they express themselves in development, and how changes may arise within them as well as in their assortment or distribution.

Since Darwin's day, the list of demonstrably heritable characters has been greatly increased, but many if not most naturalists would agree in excluding somatic modifications or 'acquired characters'. The modes of inheritance tend to be reduced to Mendelian formulae, though many still believe that some pairs of characters, differing in the father and the mother organism, may blend in the offspring.

Perhaps there has been since Darwin's day an increased clearness as to what heredity is. It is no principle, fate, or force, but a relation of genetic continuity between successive generations, admitting of variations as well as ensuring the general persistence of specific organization. It includes the study of the measurable differences as well as of resemblances between successive generations. The distinction between re-impression of peculiarities and their transmission or hereditary continuance has become clear, as also the difference between the inheritance of a disease and the inheritance of a predisposition towards it. Of considerable practical importance also is the distinction between ante-natal infection and the hereditary continuance of a disease. There is value in the recognition of the fact that the expression of a character in the course of the development is always the resultant

of two components—the hereditary 'nature' and the environmental, nutritional, and functional 'nurture'. For this takes the fatalistic edge off heredity. Finally there is clearness in distinguishing between the natural inheritance (to use Sir Francis Galton's phrase) enregistered in the germ-plasm, and the extra-organismal heritage embodied in traditions and permanent products, forming, indeed, part of the environment in the wide sense.

§ 5. *Changes in regard to Sifting*

The essence of the Darwinian contribution to aetiology is the theory of Natural Selection—the sifting of tentatives, the winnowing of experiments. Darwin had a very broad and subtle view of the manifold processes of selection, broader and subtler than many since. Those naturalists are in line with Darwinian tradition who distinguish various modes of selection, e.g. lethal and reproductive, sexual and germinal. In a few cases, like Weldon's crabs, the actual working of Natural Selection has been demonstrated. Similarly, to take a diagrammatic case, Cesnola tethered brown Mantises on withered herbage, and they escaped their enemies; and green Mantises on green plants, with the same result; whereas brown insects on a green background, or green insects on brown, were soon picked off.

It is clearer than it once was among the non-expert that selection need not mean immediate elimination of the relatively less fit, for the same final result may be reached by handicapping, e.g. if the relatively less fit organisms have a shorter and harder life and a smaller, less successful family. The common misunderstanding is dying, that the survival of the fittest need mean more than the survival of the relatively fittest to a given environment. The tapeworm survives as well as the

Golden Eagle. At the same time, when we take a long view, there has been a *general* increase of differentiation and integration in the course of organic evolution.

Of great importance is the fact that Natural Selection operates in relation to a system of inter-relations—the web of life—already established, for this explains why Shibboleths may have survival value. A nuance in the inter-relations between flower and bee may be decisive, and it is so all round. Moreover, the establishment of inter-relations gives some external security for progress. There has been an evolution of sieves as well as of the material to be sifted.

Another step is the recognition of the importance of Isolation in its varied forms—geographical, habitudinal, temporal, and temperamental—for isolation tends to inbreeding or endogamy, which stabilizes a stock or species, whereas outbreeding or exogamy promotes variability, sometimes almost like an epidemic. Alternations of inbreeding and outbreeding have almost certainly meant much in evolution.

It seems fair to say that, since Darwin's time, the range of the fortuitous and mechanical in evolution has shrunk. Darwin once spoke of the beautiful hinge of some bivalve shells, from which men used to argue to the skill of the 'Divine Artificer', to use the rather terrible phrase of those days. But Darwin said that what had come about in the shell was more like the formation of the beautiful snow-wreaths which we see when there is a snowstorm in windy weather. But perhaps the comparison did not show Darwin's usual shrewdness. For we can give, in proportion to our knowledge of the facts, a satisfactory mechanical description of what happens in the making of a snow-wreath, whereas we cannot give any mechanical re-description of the origin of really new mutations, nor of the way in which the chick is minted

and coined out of the egg, nor of the ingenuity with which animals play the hand of cards with which they have been endowed. It is true that the environment often selects organisms, but it is also true that organisms often select their environment, and in the use of their hereditary talents do commerce with circumstance. In short, living creatures are not passive pawns; they play their own game. Organisms take a share in their own evolution.

Purpose is a scientific concept when we are dealing with some known agent; we may legitimately speak of the intelligent purpose of the dog and the instinctive purpose of the bee. But to speak of purpose in Nature or in Evolution is to go beyond science in the strict sense; we are passing to philosophical interpretation. Yet we cannot refrain from trying to see things 'whole'. The old lady marvelled at the providential way in which big rivers ran past big towns; are we repeating this naive mistake when we call attention to the abundant availability of C, H, O, N on or near the surface of the cooling planet, to the almost unique property of water which keeps pools from freezing solid and thus allows of freshwater faunas in North Temperate countries, to the broad foundations of small fry that make higher animals possible, to the conservatism in evolution that holds fast that which is good, such as amoeboid movement? It often *seems as if* a multitude of factors conspired towards a progressive result. We often seem to hear the order and purposiveness of an onward advancing melody. The institution of the order of Nature must have been well thought out.

§ 6. *Manifold Influence of Darwinism*

The influence of Darwinism on modern thought and life is too big for more than *illustration* in an hour's lecture. We should have liked to show how Darwinism

was the leaven that made Psychology a new science—comparative, genetic, and concrete; but that in itself is a long story. We should like to have asked how far philosophy has been influenced by the demonstration of continuity in Nature and Man; or how Pragmatism is in some measure a recognition of the struggle for existence in the world of ideas. But we must restrict ourselves to three illustrations—the influence of Darwinism on Sociology, on Religion, and on everyday human life with its hopes and ideals.

§ 7. *Influence on Sociology*

How has Sociology been influenced? The foundations of sociology doubtless began to be laid whenever human societies began, but as a definite science sociology is young, and all but its earliest development has been under the influence of evolutionism. It has been genetic from the start, and has not undergone a metamorphosis like biology and psychology. From the moment of its modern formulation, by Comte and Spencer, it has been influenced by the demonstration of man's solidarity with the rest of creation, and by the idea of evolution going on here and now.

But just because sociology has grown in Darwinian soil it has run certain risks, from which it has suffered. Ideas which had been suggested *by human affairs* to biology, returned to sociology with a biological imprimatur, and sometimes with a false simplicity. We mean such ideas as Division of Labour and the Struggle for Existence. For a time it was almost like a game to press analogies between the individual organism and the so-called 'social organism', between the Realm of Organisms and the Kingdom of Man. More serious was the utilization of biological generalizations to justify human practices. War was justified as the logical outcome of the

struggle for existence, and *laissez-faire* slackness was justified as congruent with the regime of Natural Selection. 'Leave things alone; the survival of the fittest will follow': the silly cackle continued. Because there have been 'Lost Races' among animals, extinctions without any residue of descendants, it was argued that every human race or nationality *must* reach its limit and then decline. Next day the talk would be about the inevitableness of progress, the previous day's convictions in regard to degeneration and lost races being forgotten.

It is not reactionary to indicate the grave danger of 'biologisms'. Just as a materialism is the simplicist fallacy of forcing vital facts into mechanical frames, constructed for a different order of facts, so a biologism is the simplicist fallacy of trying to make sociology a department of the study of mammals. Up to a certain point there is a legitimate biology of mankind, and one wishes one knew more about it. An albino child is a human *mutation*; tanning under a tropical sun is a human *modification*; hereditary characters have for their vehicles twenty-four or so chromosomes in the human *germ-cell*; the differential death-rate in mankind sometimes illustrates *Natural Selection*. All that is clear. Man is a mammalian organism, and illustrates biological formulae. But he is also a rational and a social organism, a 'political being', a member of a society in which the whole is more than the sum of the parts.

What are the big differences which change the venue? The sociological unit is a societary form; variations are no longer confined to the germ-plasm; great men, big ideas, and social organizations count supremely; there is a social heritage—or, under another aspect, we may call it the social environment, which is as supreme as the Natural Inheritance is fundamental. Moreover, the selective processes are now in great part rational, or, if

not rational, more or less consciously realized. It is only necessary to state these differences to see how unscientific it is to try to force social affairs into biological frames. Every suggestion from biology must be verified in the higher field. This has obvious practical corollaries, for a proposal which is justifiable biologically—the euthanasia of incurables, for instance—may be quite invalid sociologically. Here also, we have to face the dilemma of civilization that the growth of social sentiment tends to favour the continuance and even the multiplication of undesirables, who would not be tolerated under Nature's regime, where there is no place for the unlit lamp and the ungirt loin—unless indeed in parasitism. Man's kindness in the present is apt to mean cruelty in the future.

§ 8. *Influence on Religion*

It appears that Man has usually become religious at limits of his practical, emotional, and intellectual tethers. Now Darwinism with its corollary the Control of Life means more power, and therefore, in proportion, less need for, let us say, offering gifts to propitiate the gods. On the other hand, it is only to the shallow-witted that the world has become through Darwinism less wonderful, less beautiful, less fundamentally mysterious. The emotional path to religion remains as open as before—perhaps more clearly open. When the half-gods go, the God arrives. The Darwinian world is grander than Paley's. And as to the limit of the intellectual tether, we get there soon enough even with all the light of Darwinism to illumine our thinking. For biology tells us little of more than chronological beginnings, e.g. that birds emerged from a reptilian stock in the Jurassic age; it tells us nothing of essences and very little of more than the modes of becoming. What science is always saying

is: 'If this, then that' ; or this occurrence is a particular case of laws VII and IX. But the concepts of these laws or descriptive formulae are big with mystery—organism, protoplasm, development, and the like. We venture to say that Darwinism leaves plenty of room for religion from the intellectual side. Of course we must not be taken as suggesting that religion is a sort of crutch for our weakness or a pillow for our weariness—something to be apologized for. It is rather of the nature of an enrichment, like music, if we are strong enough and open-souled enough to use it.

This change, however, has come about—a change in our understanding of the aim of science. Its aim is to describe and formulate, whereas the task of religion is to interpret transcendentally. Science is ever reducing the fractions of reality that we know to their lowest common denominator; religion seeks for the greatest common measure—the Will of the Absolute. In general, no conflict should be possible between religion and science, unless we try to speak two languages at once. This is no return to idea-tight compartments, science in one and religion in another; it is simply a recognition of the fact that scientific (empirically descriptive) concepts and religious (transcendentally interpretative) concepts are *incommensurable.* The title of a book, *God or Natural Selection,* is a diagram of the pernicious fallacy we are condemning.

Science must never dance to the piping of religion or theology, but it is open to the religious thinker to say to the biologist: 'Are you sure that your Darwinian concept of the struggle for existence is accurate and adequate?' And there are many similar questions possible. In the uplands of mysticism, science has no right of way. The only conflict between science and religion is when particular forms of religious ideas are in detail at variance

with scientific descriptions. Thus a literal, one may say wooden, acceptance of the Genesis poem regarding Man's origin contradicts scientific description, but that is not to say that there is no contribution to Truth in the religious poetical interpretation. Similarly, as exoterically expounded, the theological doctrine of the Fall is unacceptable scientifically, for it is an ascent, not a descent, that we have behind us.

It is not very difficult to see that a Doctrine of Creation may be rehabilitated as a religious interpretation of the Institution of the Order of Nature; and when Dame Nature in Charles Kingsley's *Water Babies* said to the child who expected to find her very busy, 'You see, I make things make themselves', the idea suggested is a teleology deeper than the old doctrine of design and not inconsistent with Darwinism. On the other hand, the doctrine of the resurrection of the body in its usual literal form seems an insult to the scientific intelligence. If it be said that religious feeling and interpretation are generically independent of particular forms, then the remarks we have made will refer to the influence of Darwinism on *theology* rather than on religion.

We have spoken, on the other side, of the right that the religious thinker has to inquire into the adequacy of a scientific statement when that passes beyond the field of exact knowledge. That inquiry may be made, for instance, in regard to the biological account of Man's place in Nature. The demonstration of Man's affiliation to the highest order of mammals was certainly a great gain. It gave a new unity and continuity to the whole world-process; it gave a new significance to the long groaning and travailing of creation. But there is often a tax to pay on a big intellectual gain, and in this case the tax has been an occasional unworthiness in our thoughts of Man as one 'whose grandfather was a monkey'.

No doubt there is an all-pervading similitude of structure between man and the highest apes, bone for bone, muscle for muscle, convolution for convolution; man is a walking museum of relics, some of which go back to a remote aquatic ancestry; in his individual development he climbs up his own genealogical tree; in his relapses he betrays his ancestry. Now it is no doubt profitable at times to look on the rock whence we were hewn and the pit whence we were digged, but there are other profitable directions in which we may look. 'What a piece of work is a man! how noble in reason! how infinite in faculty! in form and moving how express and admirable! in action how like an angel! in apprehension how like a god!' Part of the truth lies here.

The apartness of Man remains, whatever be his pedigree. Shakespeare is not less great because once a silly child; Man is not less great because a scion of a stock common to him and the Gorilla. His apartness is in his big brain, his language, his conceptual reason, his morality, his ability to envisage and control his own evolution.

Think for a moment of what the objective facts suggest. There is a solemnity in the patience of the age-long man-ward adventure which has crowned the evolutionary process upon the earth. Two or three millions of years ago the Primate stem sent out its first tentative branches, and the result was a tangle of monkeys. First the New World monkeys diverged, and then those of the Old World; the main stem grew on. It gave off the lower Anthropoid Apes, and then the higher, but the main stem, vaguely known, probed on. Without haste, without rest, and sometimes leading to nothing, more branches were given off—tentative men, eventually: Pithecanthropus the erect, the slouching Neanderthalers, the man of Heidelberg and of the Sussex Weald. In none of these, they say, was the ancestor of the modern man type.

The Neanderthalers had their day and ceased to be—the main stem split into African, Australian, Mongolian, Indo-Aryan and European races. The story is so remarkable that we feel the vulgarity of saying that Man sprang from a monkey. We question rather whether there is not a purpose at the core of the world-process.

This, at least, we would plead for—trying to see the process as a whole. When we are dealing with the significance of any process, we may get glimpses when we consider a particular transition. From reptiles sprang birds—there is significance in that. It meant a movement to greater integration, more emancipation of mind, more freedom of body, a richer life, and more satisfaction in life. But think of the entire evolution in the light of its outcome—which includes Man. And there is no reason to believe that achievements are all in the past!

§ 9. *Influence on Life*

Our last question concerns the influence of Darwinism on ordinary human life, and here we must confine ourselves to a couple of illustrations. The first concerns the 'Control of Life', which is to Darwinism as works to faith. When it became clear that out of the crab-tree by the wayside, more promising in its flowers than in its fruit, man had evolved all the aristocrats of the orchard, the question was bound to arise whether man might not evolve some of the crabbedness out of himself. When it became clear that out of a wolf man had evolved the domestic dog, the trusty guardian of his herds, the question was bound to arise whether man might not evolve some of the wolfish out of himself.

Pasteur might perhaps be taken as the figurehead of the modern idea of the scientific control of life, though Francis Bacon was quite clear that the aim of science was not only 'the glory of the Creator' but 'the relief of

Man's estate'. When one thinks of the triumphs of modern medicine and sanitation, when one gathers together the *practicable* suggestions of Eugenics, Eutechnics, and Eutopias—the amelioration of Folk, Work, and Place, one sees no limit to what Man may do in taking fuller possession of his kingdom. It is certain that a closer linkage of science and goodwill may remove shackles and handicaps that hinder Man gratuitously, and may thus leave him more free for higher adventures.

The second illustration is more subtle, yet surely not far-fetched. Every one remembers Huxley's picture of Animate Nature as a vast gladiatorial show, a dismal cockpit, a Hobbesian warfare—each for himself, and extinction take the hindmost. Man, Huxley argued, must, in his ethical endeavours, turn his face in the opposite direction—*solus contra mundum*. But while Huxley painted one aspect of Nature in his lurid picture, there is another which is at least equally true. There are modes of the Struggle for Existence in which the solution is found in an increase of parental care, in experiments in mutual aid and sociality. Goethe wisely said that Nature was always taking advantage of her children's capacity for self-forgetfulness.

But may we not go farther? Progress is a human concept, implying a judgement of values. It means the fuller embodiment of the True, the Beautiful, and the Good in lives which are increasingly a satisfaction in themselves; and the pre-conditions of this progress are Health and Wealth, meaning by Health not merely the absence of disease, but positive vigour, and meaning by Wealth a happy mastery of the requisite energies.

Now the main movement of evolution has been integrative and progressive. It has meant the emergence of nobler, finer, more moralized types. It actually discloses movements which are the counterparts of man's

endeavours after the True, the Beautiful, and the Good. Nature is all for health and all for beauty. She rewards the creatures that face the facts, which is the beginning of the search for truth. She gives the premier place to those that have learned the lesson of self-subordination. The momentum of evolution is behind us when we are at our best.

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IX

SCIENCE AND EDUCATION

A. E. Heath

I

Our common task, in this course, is to discuss the relation between science and social progress. Such a line of work falls naturally into place as part of a wider movement towards a fuller appreciation of the basis of science upon which modern social structures are built. This movement has two main streams.

On the one hand a growing band of scientific workers have turned their attention to the building up of a real history of science, and of a first-hand account of scientific procedure. What is aimed at is not a history of trivial biographical detail, but a real treatment of the evolution of scientific ideas; not a philosophy of science which consists in the spinning of a fine web of *a priori* constructions out of the philosopher's superior wisdom, but a critical attempt to obtain a general synthetic view of scientific concepts, methods, and principles from a careful survey of their actual use in the hands of scientific workers themselves. These studies must inevitably have important bearings upon any serious attempt to estimate the influence of science on the thought and on the material organization of the world we live in. In particular they will enable us to avoid a too narrow interpretation of science as a body of fact, and will turn our attention to science as what Professor Nunn has called a 'grand expression of the human spirit'.

On the other hand we have a closely associated move-

ment among those modern historians who are dissatisfied with the older over-stressing of the political aspects of history. Once we accept the view that history is the account in full of man's achievement, of his increase in knowledge as well as in the power which comes from knowledge, then the character, growth, and influence of science form an important part of that study.

In broad outline we may anticipate our conclusions and say that the two parts of this movement exhibit science as an age-long process which has enabled man to trace ever more complete uniformities and correlations in his world, and has given him in consequence new powers of control. From the first of these comes a deepening sense of social unity; from the second, an intensification of social responsibility. It is a fatal mistake to exaggerate the degree of rational unity reached by man: nevertheless he does seem to be groping towards ever more consciously directed control over the social institutions (including education) whose growth has been, however dimly and inadequately, an expression of his social unity.

Now it is clear that if, with these considerations in mind, we ask what has been the influence of science on that part of social organization we call education we are entering upon a vast field whose full treatment may well employ generations of workers. We can only, in our brief survey, choose a single aspect of this subject; and even within the limits set, only attempt a preliminary and tentative treatment. If we confine ourselves to English education, it still leaves our subject too wide: English education is a growth whose continuity is being more and more emphasized in recent work. Nevertheless we can justify the further limiting of our subject to the modern period. For, as Professor Archer has well said, 'Institutions are not like plants which grow from a seed into a predetermined shape; they are transformed into

something radically different by a creative period, and such a creative period was the nineteenth century.'[1] Again, in treating our narrower subject we must guard against any implication that the creative force with which we are here concerned—the intellectual movement centred in the sciences—was the only moulding force acting in this period. The ferment in the public schools during the middle of the nineteenth century and the enlargement of classical studies called 'classical humanism' are examples of other important forces whose effects are clearly discernible in the educational theory and practice of our own time. We must however recognize that any adequate treatment of the influence of science on modern education must embody the important fact that it has been *more* than the impact of an intellectual movement. In addition to its primary influence on education, science has itself affected social organization in general and produced secondary influences arising out of the changes so induced. In revolutionizing the methods of production in modern times it has, for instance, affected the functions of the State, precipitated social movements, and raised new and urgent problems—all of which, in turn, react on educational theory and practice. We may express this by saying that our age is one (*a*) whose material characteristics are closely connected with scientific progress and (*b*) whose thought is saturated with scientific ideas. In view of this double character it will be convenient to make a twofold division in our treatment of the influence of science upon modern education, and to distinguish between (1) the influence of scientific results, and (2) the influence of the method and outlook of science.

[1] R. L. Archer, *Secondary Education in the Nineteenth Century*, p. 1.

II

The most important general influence of scientific results has been referred to above, namely the revolution brought about in the methods of industry. Modern students of the industrial revolution draw a distinction between the earlier change from individual to organized production and the later changes resulting from the application of the results of the physical sciences to industrial processes. This distinction is important because it emphasizes the continuity of the movement. The change in the last decade of the eighteenth and early decades of the nineteenth centuries was only an acceleration of what had been taking place before. The social consequences are not, that is to say, to be sought entirely in science; and the more evil of these consequences seem to come, not from improved powers of production alone (it seems incredible that they should, though many people write as if they believed it) but from the rapidity of the changes in view of the special character of the time. This point we must stress because it has an important bearing not only upon our view of the direct influence of this social upheaval upon education, but also, as we shall see later, upon our view of the influence on education of the method and outlook of science. Professor G. W. Daniels has stated the case with great clarity in his *Early English Cotton Industry*.[1] The idea that a movement characterized by a greater power of production and by an expanding economic unity could, of itself, be a cause of widespread distress and of social retrogression is, he says, a hard one to accept. He points out that in consequence of the Napoleonic war the economic changes were probably concentrated within this country to an extent they would

[1] Ch. v, pp. 145–8.

not have been in time of peace; and he shows that contemporary movements which were making for social development were checked by war-time class-legislation. The Napoleonic war, he concludes, thus becomes the dominant factor in the social and economic history of this period. Owing to its occurrence the whole movement was distorted, the increasing power of production was diverted from improving the material welfare of the community, and problems of industrial relationships which might have been faced at once were left as a heritage to the nineteenth and twentieth centuries. In the light of these conclusions we can see that the influences on education of the applications of science to material production are twofold.

(*a*) In the first place the increased control of man's material environment, whether misused or not, carried with it important consequences. A complex industrial machine cannot be reared on a foundation of unskilled work. 'The need for elementary and technical education, which became urgent at the beginning of the nineteenth century, led to the reconstruction of the whole system of national education upon a new basis.' [1] Moreover, the intrusion of organized scientific results into everyday life compelled the admission of scientific subjects into every grade of school and into university studies. An elaborate account of the fight of science for a place in the curriculum would tell us less than the bare fact that 'artisans studied science before Cambridge undergraduates knew of it'. [2] To these consequences we may add the slow secularization of educational control.

(*b*) In the second place, the evil consequences of the

[1] Sir Michael Sadler, *Lecture Courses in the Department of Education, University of Manchester*, 'History of Education in England 1800–1910,' xvi.

[2] R. L. Archer, loc. cit., p. vii.

industrial revolution precipitated social movements which in turn affected education. We need only recall the influence, both direct and indirect, on educational thought of Ruskin, Maurice, and Kingsley. It is precisely here, however, that a just estimate of the place of science in the chain of causes becomes important. We have seen that the evil consequences of industrialism had other origins than mere increase in productiveness. Unfortunately this was not always recognized; movements against preventable evils were occasionally directed also against the whole idea of scientific production and even against science itself. Our own age is not entirely proof against this confusion of causes: and from it, I feel convinced, comes a great part of the current belief that science is a piece of soulless intellectual machinery tending to the standardization of men and things, and to the ultimate destruction of finer shades and values.

It is true that increased productiveness has left man with the immense and as yet unsolved problem of its effective control; but the gospel of despair preached by those critics who observe only the lack of such control, and lay them at the door of science, brings to the ordinary man neither conviction nor encouragement. The view here taken is that it is only by the application of the method of science to the problems of control in turn that any hope for the future of mankind lies. In education, too, it is true that—for a variety of reasons—the first developments of national primary education were stiff, standardized, and in a literal sense lacking in values. But here again it must be observed that scientific results have greatly helped, as the century advanced, in the growth of a more rational and humane outlook; whilst the mode of co-operative investigation in the sciences probably influenced the official labours on the administrative defects of the earlier systems. The extension of

scientific method to the field of biology, which is the outstanding characteristic of the later nineteenth century, emphasized the organic unity of the life of the community, and so gave a new significance to the responsibility of providing for all the conditions necessary to healthy mental and physical growth. But it did more than merely help the drift towards a national system of education: it provided solid ground for a reasoned first-hand study of the sensitive growing creatures who were to be subject to that system. The biological outlook, with its concept of development, does not leave men content with the formal and one-sided education which was considered good enough for the mass of children in the middle of the nineteenth century. The extension of scientific method to the domain of mind has in turn added its important part to the tale of the influence of scientific results on educational theory and practice. But as we approach the twentieth century it becomes less and less possible to differentiate between influences of results and influences of method, because man's whole attitude has been so profoundly modified by the latter.

Before attempting, however, to deal with the influences of method, it is necessary to state as plainly as possible that the method and outlook of science have meant different things at different times and to different people. Moreover, as has been hinted above, what men have taken them to mean, as well as what they really were, affected thought and practice. Hence some inquiry, however inadequate, into the meaning of science regarded as an age-long growth is a necessary preliminary to a treatment of the influence of 'scientific method' on education. All that can be attempted here is a mere sketch of the lines along which such an inquiry might be pursued, in the hope that the digression may justify itself by the light it throws on our main theme.

III

The first question which arises is whether any intelligible meaning at all can be assigned to 'scientific method' in view of the fact that there are so many different sciences. If 'method' be conceived as the result of abstracting many 'methods', and comprising a kind of generalized research tool whose use can be learnt before it is applied to any field, then the answer is emphatically No. But 'scientific method' may be regarded as something rather different from this: as *a characteristic mode of approach to the study of any field of human experience.* In each actual field, on this view, workers will employ 'methods' common to other fields, but to which its users will give slight shades of emphasis or meaning that impart to them a form typical of that special field. Moreover the balance of 'methods' used will vary from field to field. Thus, what pieces of logical apparatus are used, and their relative importance in the whole, will depend entirely on the domain chosen. In the domain of light, for instance, deduction plays a much greater part than in anatomy: yet I believe that a very real meaning attaches to saying that both physicist and anatomist employ a common mode of approach to their respective domains. This was what Huxley meant by claiming that different habits of mind and various special tendencies of two sciences do not imply a difference in method. 'The mountaineer and the man of the plains have very different habits of progression, and each would be at a loss in the other's place; but the method of progression, by putting one leg before the other, is the same in each case.' [1] There is a curious relevance in this metaphor to the view which will here be expressed as to what this

[1] *Science and Education*, 'On the Educational Value of the Natural History Sciences', p. 57.

common mode of approach to different subjects is: for I take it to consist essentially of two processes whose alternations are comparable to the placing of first one and then the other foot forward in walking. These processes are (1) the observing and testing of a body of facts, and (2) the 'ordering' or systematizing of those facts, by the discovery or creation of appropriate conceptions and hypotheses, into general and easily grasped truths.[1] Knowledge of a chaotic body of facts does not constitute a science. To step (1) has to be added step (2) That is to say, the body of fact has to be, in Professor Nunn's phrase, 'rendered intelligible'.[2] Moreover this double process is never finished, for the ordering of any field always directs attention back to a closer examination of the body of fact. Theories constructed to co-ordinate facts lead to the discovery of additional groups of fact; these, in turn, are susceptible of further ordering, and so on in an endless series.[3] It should be carefully noted that both steps are essential. In certain periods the need for constant critical and first-hand observation was overlooked, and science degenerated into system-building; in other ages there have not been wanting those who regarded empirical and experimental processes as the sole requirement in scientific work, a denial of man's most valuable possession—the power of imaginative reason.

[1] This view is developed in more detail in a paper on 'The Scope of the Scientific Method', *Proc. Aristotelian Soc.*, 1918–19, pp. 179–207.

[2] T. P. Nunn, *The Aim and Achievements of Scientific Method*, ch. 2, pp. 46–62.

[3] It is this which renders sterile a certain type of criticism of science according to which its hypothetical, 'ordering' constructions lead one away from direct experience into systems of 'knowledge about' experience. For an able statement of this Bergsonian view see Mrs. Karin Stephen, *Proc. Aristotelian Soc.*, 1917–18, pp. 69, 71.

For healthy scientific development a proper balance between the two factors must be maintained.

It is important that we should recognize that scientific method, viewed in this way as a mode of approach to the study of any subject, has, through many vicissitudes, been first attained in its complete form by man in the domains of mathematics and of external nature. It is this which has led to the everyday use of 'scientific method' to designate that mode of treatment of a field which is seen in its most unquestionable form in the domain of the natural sciences. In common speech something quite definite is meant by saying that a man is tackling a subject in a scientific manner; and what is referred to is not the methods used so much as the manner of wielding those methods. This is the justification for our usage; though it must be admitted that the word 'method' is in some ways an unfortunate one in this connexion, because it tends to confusion with 'methods'.

The utility of this usage for our present purpose is that it enables us to envisage science throughout the ages as a single development. Thus in broad outline we may say that in Greek science at its best this balance was won. Its first victory was in the domain of spatial experience; and the importance for thought, in all fields, of the step from the empirical results of Egyptian mathematicians to the general theorems of Greek geometers cannot be over-estimated. Greek geometry, the first fruits of the method, not only developed the logical machinery necessary for the scientific mode of approach to the world of external nature, but also fostered the objectivity of outlook essential to that approach. Especially in those domains of nature where deductive processes play the most important part, the emergence of a balanced 'scientific' treatment became possible. This balance was lost again in succeeding ages, in which—for complex reasons—

there is a failure to value step (1). Thus much mediaeval scientific work may be regarded as coming under this description. It should be noticed, however, that such work often serves a real function in co-ordinating known facts and views. Thus Dr. Singer, in his account of 'The Scientific Views and Visions of Saint Hildegard (1098–1180)', speaks of the use of the supposed relations between the macrocosm and the microcosm as a co-ordinating conception in which her theological and physiological knowledge, together with her notions of the working of the human mind and of the structure of the universe, are all synthesized. 'In studying it', he writes, 'the modern reader is necessarily hampered by the bizarre and visionary form into which the whole subject is cast. Nevertheless the scheme, though complex and difficult, is neither incoherent nor insane . . . this theory of the essential similarity of the macrocosm and microcosm held in the Middle Ages, during the Renaissance, and even into quite modern times, a position comparable to that of the theory of evolution in our own age. If at times it passed into folly and fantasy, it should be remembered that it also fulfilled a high purpose. It gave a meaning to the facts of nature.'[1] Nevertheless the lack of stress in mediaeval science on the first factor carried with it loss in objectivity. It therefore represents a falling away from 'the direct, detached, objective temper' which has been spoken of as the generative principle of the whole Greek achievement for civilization.[2] In short, it was a regression to a more primitive form of treatment, and only a little way separates it from an earlier form still—animistic magic. Magic, like mediaeval science, is too personal; men read themselves, their feelings, and their desires into their explanations of the world. Animistic

[1] *Studies in the History and Method of Science*, vol. i, p. 32.

[2] R. W. Livingstone, *The Legacy of Greece*, p. 274.

interpretations, however, like anthropomorphic ones, still perform a true co-ordinating function.[1] But there is this important further character of magic: it is developed in a much less conscious and less deliberate way. The origin of sympathetic magic, for instance, does not appear to be intellectual illusion. The first element seems to be the immediate discharge of longing in action. If the savage wants rain he 'acts' rain by croaking as he has heard frogs croak when it rains. These acts stiffen into ritual, on this view; and beliefs in the efficacy of similarities follow later. Magical beliefs and practices are not mere unorganized collections of baseless superstitions, then, any more than mediaeval science is altogether incoherent and insane. Both are primitive forms of approach to the study of the world of nature.

We can now return to our claim that this view of scientific method enables us more clearly to envisage the sciences as age-long growths. So long as they were the product of unreflective acts they could only take the stiff and self-centred form of magical beliefs, corresponding to the social organization which Bagehot called the 'cake of custom' of primitive societies. In some marvellous way we find, in ancient Greece, that the complete break-up of the cake of custom has been suddenly effected. Not only is man's outlook on the world now fully deliberate and conscious, but also it has become objective. The loss of objectivity in later times was not, however, a complete regression to magic: for though mediaeval astrology was primarily concerned with human hopes and fears, and only secondarily with the stars, yet its vision did reach to the stars. Nevertheless lack of appreciation of step (1) made even the newly gained knowledge of Greek scientific results sterile for centuries. The rediscovery of what Roger Bacon called *scientia*

[1] T. P. Nunn, loc. cit., p. 46.

experimentalis was needed to revive the objective temper essential to real scientific method. The growth of this can be traced through transitional figures like Kepler to its full fruition in Galileo. The seventeenth century saw the double process of direct observation and ordering into systematic wholes applied to the complete field concerned with the study of the rest and motion of material bodies: it was the age of mechanics. Succeeding centuries saw the extension of this double process into ever wider fields of human endeavour: to various physical forces in nature, and to the field of chemical fact, in the eighteenth century; to the domain of biology in the nineteenth; and in our own time, to the realms of mind and the products of mind, including social institutions.

It must not be supposed, however, that this extension of scientific method to different fields means that scientific development has been a steady, uniform process in the last three centuries. Actually each age seems to have its own peculiar scientific 'flavour'.[1] Thus there is a certain disconnectedness in the science of the sixteenth century: it was more like the spasmodic inventiveness which still connotes 'science' in many minds. Whereas the seventeenth century saw the beginnings of an interconnected character; results in one field were used in another—as when Galileo, hearing of the invention of the telescope, constructed one, but turned it at once to astronomical use. Co-operation between workers in different fields became common; and most of the great European scientific academies were founded in this century. This characteristic was an essential element in future progress, for without it the ground could not have

[1] This is strikingly shown in chronological charts of scientific history. I have found it useful to make such charts with a 'background' of events of importance in the history of social movements and of the various arts: the close connexion between different human activities are thus thrown into relief.

been cleared of the age-long accumulation of systems which cumbered it. Individual men working in isolation could not cope with the enormous labour of testing such systems by patient reference back to the field of fact upon which they claimed to be reared. This probably had some part in the failure of the first attempt in England, in the middle of the seventeenth century, to introduce science into the school curriculum. The balance had already been re-won: the mode of approach to these studies had regained its objective character. But if educational reformers like Comenius, claiming to be followers of Francis Bacon, had succeeded, the teaching of science would almost certainly have degenerated under the stifling influence of the accumulated systems to whose sifting the co-operative labours of scientific workers in this and succeeding ages had to be devoted. Moreover the Baconian account of method was little more than an early attempt at that abstraction of 'methods' into a generalized research tool whose possibility we have been forced to deprecate.

IV

It has been previously suggested that the treatment of the second main division of our subject—the influence upon education of the method and outlook of science—ought to include some reference to the effects of what men have mistakenly supposed that method and outlook to be. Two of these errors have enough historical importance for special mention.

The first consists in the belief that the criterion of a scientific treatment is its quantitative character. If this be so, then most 'biological science' is not science at all: and the greater part of all existing attempts at scientific treatment of the field of experience concerned with 'human' facts, whether mental or physical, is

worthless. It will be recognized, I think, that assumptions of this kind, often not explicitly formulated, underlie a certain type of educational theory. If our previous discussion of what is actually involved in the scientific treatment of a field is correct, then this view is false. Quantitative treatment is, of course, important in all sciences; but it is not essential. There can be quite systematic sciences which are almost entirely qualitative; there are, indeed, qualitative sciences which are not only systematic but also formally deductive—as for instance non-metrical geometry. The historical origin of this error lies probably in the fact that the scientific method of approach was first achieved, as we have seen, in mathematics.

The second is the commonly accepted view that the scientific treatment of a field implies that the facts of that field are ultimately reducible to mechanics; and that, in consequence, the outlook of science tends in a last analysis to materialism. The mistake here comes from non-recognition of the self-determining character of the separate sciences. It is true that there are complex inter-relationships between all studies, and that cross-fertilization is often effected by applying the concepts of one field to another. Further, it is a natural consequence of the fact that the physical sciences already possess mature and generalized descriptive schemes that biologists should seek aid from them in developing their own. And this makes it clear why they will continue to find reference to the physical sciences a fruitful methodological principle, however solemnly philosophers wag their heads at it. Yet it is a far cry from this to assert the reducibility of all the categories of one domain to those of another. Each science is, in fact, an autonomous study; and only he who is actually at work in a particular field can determine the effective form of the concepts he

requires for the ordering of that field. Just as the biologist must repel any attempt to force upon his study categories foreign to it, such as those of mechanics, so also—in another field altogether—the historian can legitimately set his face against partial interpretations of his domain in terms of other studies like economics or ethnology, and is not (in so doing) rendering his study less 'scientific' in our meaning of that adjective. From all cognate studies the worker in any particular field takes only what serves his own proper and unique purpose.

These two mistaken views blend together to create the notion that a science is essentially something antithetical to humane studies; and both views gain support from the vague feeling that the less desirable results of the industrial revolution can be referred to the physical sciences. The result has been to delay appreciation of the real character of the intellectual movement centred in the natural sciences. The development of such understanding is well exemplified in the varying reasons assigned for their inclusion in the curriculum during the latter half of the nineteenth century. Thus in Spencer's utilitarian and individualistic arguments stress was laid on the importance of the content of a subject. Later the stress is shifted, as shown in Huxley and still more in Ruskin, from the content of a study to the outlook it induces if fully appreciated and properly taught. Finally, in Karl Pearson, the weight of the argument is for science as a method of ordering any field of human experience.

A real difficulty arises here, however: for on the view developed above no general defence of the natural sciences can be based on their training in scientific method, since on that view any study may be 'scientific'. This does not mean that a useful distinction may not be made by the teacher between content and methods of

study.[1] But it does mean that he must recognize that such methods always show characteristics due to the content in which they arise. Hence if the pupil acquires the power of wielding the methods used in one field it does not follow that this power will be transferable to another. It will be observed that we deliberately speak of 'methods' as something clearly to be distinguished from 'method' in our sense of a mode of approach to a study. Yet though no general defence of the natural sciences can be based on their training in 'scientific method', we must now add that a special defence is not only possible but also rendered more powerful by this delimitation of the scope of the argument. This defence rests on the claim that the particular mode of approach which we call 'scientific' (defined as in the preceding section) is exhibited in its fullest and least equivocal manner in the natural sciences. That this is so may be due to the fact that this mode of approach was, for quite definite reasons, first attained by man in his study of the world of mathematics and of external nature: and hence such studies form the natural introduction to the scientific method or manner of approach to all other fields. This will perhaps become clearer as we proceed with our general task of dealing with the influences in education of the appearance of this 'mode of approach' upon the stage of human thought. We have already

[1] Its use is apparent if we remember that in general the teacher of any subject has two correlative aims: (1) to give his pupils as wide a knowledge as possible of the completed edifice which workers in that subject have reared in the course of its history; and (2) to induce in his pupils some 'sense' of the methods of work of those who have built up that edifice. Synthetic teaching, capable of giving sweeping views of the field of study, is essential to the first; analytical and detailed work over a selected portion of the field is essential to the second. In the one the emphasis is on content; in the other, on methods.

traced through the centuries its slow emergence in a complete balanced form, and its extension to ever wider domains of experience. The effects on education in our own age may now be exhibited as arising out of the general character of that method.

(i) The insistence upon close and critical examination of the field of fact studied and the constant reference back to it as the ordering of the field is proceeded with give to the method its character of objectivity. Now it is notoriously difficult to attain the impersonality of outlook necessary for this in those fields which more closely touch human interests. The late appearance of the 'human' studies in their scientific form is therefore only what we should expect. M. Bergson has, in one of his books, tried to imagine what might have happened if the science of psychology had appeared before the physical sciences: but the thing is inconceivable, since an objectivity of outlook is needed in the study of mind far beyond what is necessary in mechanics. This could only arise when men had developed and consolidated their gains on more neutral ground: when they had won the power of facing facts which ran counter not only to their hopes and fears but also to their preconceived theories, many of which—as we have seen—arose as secondary products of unreflective action. This character of objectivity, carrying with it what Professor Whitehead has happily called the 'first-handedness' of science, has spread to human studies in our day. It has helped educationists to recognize the value of educational experiment: it has slowly forced them to acknowledge that the touchstone of educational theories and administrative systems is only to be found in the educational laboratory—that is, in direct and first-hand experience of the effects of those theories and systems upon the living body-minds of pupils in the schools. Closely con-

nected with this objective and first-handed character of scientific method is the attitude it encourages of welcome to the unexpected. Discovery fosters susceptibility to new experiences. This attitude has especial value in education, where both in theory and practice it is, in a peculiarly complete sense, easier to deal with the normal and expected. If a clever boy who is expected to be good at mathematics shows incapacity in that study, it is easier to blame and pass on than to inquire in what that incapacity lies; yet such inquiries when pursued often lay bare failures in co-ordination, or in early training, of the highest interest and importance. Here, as in other fields, the unexpected forms the rough edge to the building—often showing where the next construction is to be. So, slowly, a franker and more unbiassed re-examination of the facts of child life is born of the modern openness of mind which no longer views the abnormal with either indifference or contemptuous pity but with attempts at understanding.

(ii) Each process involved in the second of the steps which comprise the scientific mode of treatment of a field had to be painfully won in the 'human' domains. These processes may be described as (*a*) the ordering of the facts of a field by (*b*) the deliberate creation and use of appropriate conceptual constructions with a view to (*c*) the attainment of general truths or principles. (*a*) The idea of order has only slowly developed, and with it the sense of control which that order confers. The wind bloweth where it listeth; yet discernible traces of order made possible sailing-ships and windmills. Malaria was regarded as an 'act of God' beyond man's control; but biological ordering has led to control of that element in the biological environment. Man's emotional instability and group character place him at the mercy of mob-passion; doubtless orderings in the

psychological field will forge defensive controls here too. These orderings in turn lay the basis for similar orderings in fields like education. For they exhibit man as being, of all creatures, born the least capable of coping with his environment; and yet, by that fact of a long plastic youth, of all creatures the best able to pass on his social heritage—the capitalized experience of the human race, in Huxley's famous phrase—to the next generation. (*b*) The use of conceptual constructions is as old as language; their deliberate and critical use is a different matter. Words, as Hobbes said, are wise men's counters, but they are the money of fools. The terrifying power of words and phrases over men's minds is sufficient to warn us that the distinction is a real one. Their explicit and critical employment in human studies like education would act like an electric discharge on a fog: it would clear the air. (*c*) The final aim of these processes, the attaining of general truths by the co-ordinating power of deliberately used concepts, even if beyond immediate reach in a complex human study like education, is a powerful defence against partial views. Its presence as an ideal helps the habit of wider vision and cultivates the power of looking for, and seizing upon, interconnexions between separate regions. The greatest of all evils in education has been a kind of casual disconnectedness. The teaching of snippets inside any subject, and of subjects divided off from each other in water-tight compartments, is only symptomatic of wider failure to envisage educational problems as wholes. The systematization of the concrete field of educational practice, which we here speak of as an ideal, should proceed side by side with the empirical garnering of experience. This helps practice not by presenting it with a set of *a priori* principles or rules from outside, but by turning the attention of the practitioner to the rational orderly study

of successful methods in actual use, and of the underlying reasons for their success. In Professor Laurie's pointed phrase, sound theory is only sound practice 'conscious of itself'. But it performs a wider co-ordinating function than this. Its far-reaching consequences in helping to foster a more synthetic view of education in the twentieth century would form an interesting chapter of educational history. We must be content with the bare statement that its influence can be traced in state control and investigation of education, in the unifying of educational outlook as well as of its machinery, and in the sharpened sense of social control and responsibility which is reflected in such movements as that towards effective adult education.

These influences may be summed up by saying that the field of education is proving more and more susceptible of scientific treatment. We may profitably view this statement, however, from another angle, especially as this new mode of looking at the whole question will enable us to deal more easily with certain further aspects of the influence of scientific method on education.

V

A science, on our view, is the product of a particular mode of treatment of some field of experience: but men are 'experiencing' in such fields long before this stage is reached. The mode of approach to the field has to become both reflective and impersonal before it is 'scientific'. Moreover, man is primarily, as we have noticed, a doer. In other words, sciences have their origin in crafts. They are the craftsman's experience rationalized. 'Science is born anew in that wonderful world within each man, when with deliberate will he succeeds in thinking about the principles of his work in the great world without in a clear, logical, and systematic way, and

courageously puts his conclusions to the test of experiment.'[1] Mr. Branford's stimulating conception of levels of skill enables us to clarify still further our ideas of this relation between a science and the portion of the world's work in which it has its origin. At the lowest level we have routine skill, an unconscious product of mere practice. Scientific skill is more than this: there is the addition of rational thought about practice, and the consequent understanding brings added power. Directed by consciously acquired principles skill becomes deliberate and communicable by language. A science is born. But there is a still higher level in this hierarchy: that of aesthetic skill. The word is used, of course, in a very wide sense; it is as applicable to the work of a physicist or mathematician as to that of an artist. It consists in the possession of what Professor Whitehead has called that most austere of all qualities—a sense of style. It is the elusive rightness which distinguishes the work of the artist from that of the technician, and is incommunicable because it reflects the individual and unique quality of its possessor. This highest form of skill is built up on, and may be helped by, scientific skill; but it does not necessarily crown it.

Education, on this view, is more than a science: it is a craft. The science of education will be to the practical educationist a servant whose usefulness grows with his own growth in experience and skill; and it will appear as the product of a particular mode of utilizing his experience to extend the scope and level of his activities. From the action of thought on work emerges a synthetic novelty, scientific skill; but work is the basis. 'Don't learn to do,' said Sam Butler, 'but learn in doing.' Our schools, however, still suffer from the divorce between work and thought which is, in part, a heritage of the past: a relic

[1] Benchara Branford, *Janus and Vesta*, p. 185.

of the time when man's social heritage had to be so largely re-won from books. This disjunction has not gone without protest, and in our own time attempts are being made to remedy it. It is part of the great work of Sanderson of Oundle, for example, that he asserts, in all subjects, that real work amongst concrete problems is the ground out of which flowers any systematic thought about these problems which is worthy of the name. If once men realized this, if they knew that problems in any field of human study cannot be solved by fair words and polished phrases, but only by hard work, then your man of affairs might be persuaded that learning could be good fun and a worthy occupation for grown men. Sanderson did not stop, however, at asserting that the divorce between thought and work, pure and applied science, was wrong; he pointed to its evil effects. It encourages, for instance, the tendency of teachers to use the logical order of treatment, in which one passes from the logically simple to the complex. But this often means a premature appeal to the system-making motive. The motive of wonder or romance, the unsophisticated delight in natural phenomena: or that of utility, the 'how does it work?' motive—either of these may be appealed to in such early stages. But the craving for theoretical completeness and unity, for the trim tidiness of deductive systems, comes—if at all—later. Sanderson's sympathy with the average boy's appreciation of the concrete thing, and especially of new scientific creations, led him to inquire whether a teaching order which was the exact reverse of the traditional one might not be more effective. Instead of beginning the study of mechanics with the abstract and formal definitions of the older text-books, the boy was to be set to work in an engineering laboratory in which he would pick up 'by contact' rough but concrete notions of such things as force and

momentum for himself. These he could use as tools for further advance, leaving their exact definition to a later stage. It should be observed that such courses are of a preliminary character. Systematic treatment is not discarded, but only deferred.

Sanderson's work goes further than this: his social message is a natural outcome of his main view. When he says that he wants scientific men to claim a larger share in the work of the world, and not to confine themselves to what is commonly called science, he is insisting on the extension of the scientific spirit into every field of human thought and endeavour, just as he sought to extend it into every side of school life and work. He regarded his school as a scientific laboratory, and his work as an experiment in that laboratory. By the duty and service of science Sanderson meant, therefore, that scientific men should bring their ideal of life, their vision, and their methods to the problems raised by the social structure which science has itself brought into being. 'Our industrial life', he said, 'is imperfectly organized; all our troubles are due to the fact that we have a process created by science, but organized in the old way by men of a different outlook.' He saw that modern industrial processes had only been made possible by the bringing into being of alert and intelligent workers, with the consequence that the control of the whole industrial machine lags behind its power and complexity. The main lines along which a hopeful solution may be sought seemed to him perfectly clear. In his school he had tried to replace explicit teaching by 'finding out'; to replace the class-room by the laboratory, into which you went not to learn but 'to find out the things required for to-day'. Such an appeal to the constructive impulse rather than to acquisitiveness carried with it important social consequences: for though boys may be willing to 'learn'

out of sheer possessiveness, they don't want to make or discover things merely for themselves. 'I have tested that ', he wrote, 'in the workshops. They don't want to make things for themselves; they soon cease to have any longing desire to make anything even for their mothers. What they love to do is to take part in some great work that must be done for the community; some work that goes beyond them, some great spacious work.' Sanderson therefore felt that he could point out the way to hopeful advance when he said that the great thing was to enlist boys and girls in the service of man to-day and man to-morrow. And since, to him, the ideal school was a model of the world to be, he believed that this same way is the path of advance for the world outside school.

We have spent some time over this social aspect of Sanderson's educational work [1] because it illustrates so admirably the main conclusions to which we are being led concerning the influence of scientific method on education. The objectivity of outlook and the deliberate and self-conscious character of scientific treatment is urgently needed in the field of social studies. Dispassionate survey of the actual character of institutions is a rare thing because the 'ought' is so often confused with the 'is'. Studies like human biology and psychology have had to struggle through to their present 'ethical neutrality'. This does not mean that the 'ought' has no place; but it does mean that its force is very seriously impaired unless it is built upon a sound knowledge of the 'is'. Social institutions are too seldom regarded as the disorganized products of largely unreflective activity which they really are: their functions are rationalized to fit the

[1] For a fuller account see the article on 'Sanderson of Oundle and the Ideal of Science as Service', *Friends' Quarterly Examiner*, October 1922.

prejudices of the time. Systematic knowledge of what social institutions are (and of the limits of their powers—a thing often forgotten in education) is an essential preliminary to their control. Moreover, if we reflect on the suggestive conception of a 'hierarchy of skills' described above, a possibility of the emergence of values opens out which has the very highest importance in this connexion. This possibility is that values both moral and aesthetic may be a synthetic novelty proceeding out of the earlier scientific treatment of a field, just as scientific treatment itself was a synthetic novelty arising out of earlier and less reflective modes of treatment. This would, if it could be substantiated, throw a happy light on the high social and aesthetic level of Greek civilization; [1] and it might perhaps enable us to look forward to less groping and incomplete solutions of our own social disharmonies in the future. If social sciences should arise which are unashamedly part and parcel of the world's work and the world's concrete problems we might perhaps expect that they would precipitate new values based on the creative aspects of scientific discovery: and only such values can free the scientist from his earlier bondage to mere blind productiveness, and preserve him from acquiescence in the prostitution of the power he wields to unworthy ends.

[1] It might have some bearing on Dr. Singer's interesting suggestion that the re-winning of Greek science in the Middle Ages was sterile until the 'literary renaissance' had added Greek art.

X

SCIENCE AND HEALTH

F. G. Crookshank

§ 1. *Introduction*

'The office of Medicine is but to tune this curious harp of man's body, and to reduce it to harmony.'—Bacon, *Advancement of Learning*, Bk. II.

Life has been defined as the continuous adjustment of inner to outer relations. We may consider *health* as the functional unity of the organism that continues when, following repeated response to stimulus, there is successful adaptation, or adjustment to environment. Again, *disease* is no objective entity but a dissociation of functional unity, or, mal-adjustment due to failure or incompleteness of adaptive response. Now, in thus speaking of health and disease, we must learn to think, not merely in terms of ourselves and of our component organs and cells, but in terms of the higher complexes with temporal as well as spatial extension—the race and the community—of which we are components. We must realize that, for these higher complexes as well as for ourselves, with new conditions new reactions or responses occur which are at first disharmonic; but that with personal, communal and racial effort, adjustment becomes effected and harmony is again reached. Positive and final victory over disease implies an absolute stabilization of internal and external conditions, and is not compatible with progress, far less with change.

The 'special diseases' of which we speak exist as concepts of the various types of inharmonious reactions

and responses that we observe, and have in no sense 'real' or even constant—far less material—values. Indeed, the very 'diseases' against which we declare that Science is waging implacable war often represent reactions created by the social progress that we vaunt; sometimes the direct consequence of the application, to practical affairs, of that kind of accurate knowledge which is supposed to constitute Science. We must not believe, moreover, that because the application to the case of a particular individual of some item of scientific knowledge often results in benefit to the health of that individual, therefore like application to the cases of many individuals will proportionately benefit the health of the community or of the race. Both the benefit to the individual and the manner of bringing it about may be prejudicial to the interests of the race and of the community. Yet the contrary assumption is too often the foundation not only of the gratulations of health lecturers but of the projects of health reformers.

The fact is that, at the present time, social change—industrial, economic, and the like—is everywhere modifying the conditions of life more rapidly than we care to admit;—far too rapidly for the exercise of the *natural* powers of adaptation of the human race, and so Science is called in to adjust the balance. Sometimes by the logical demonstration of truths intuitively appreciated by every savage—as in the case of the so-called discovery of vitamines—Science expensively redresses the disturbance brought about by her own interference with habits dictated by racial memories. Sometimes, as by her interference with warfare, she increases quantitatively and for the community what she set out to diminish for the individual.

Thus the relations between Science and Health may be, and often are, regarded on the one hand as from a very

static platform and, on the other, as by one who is more concerned to note the succession in outlook obtained during a long and progressive ascent. Both modes of view have always obtained, perhaps they always will, and our purpose may be best fulfilled if we attempt to compare them, saying something first, in historical retrospect; next, concerning the present scientific position; and, finally, considering the matter from the human standpoint.

§ 2. *Historical Retrospect*

'Medicine is a Science which hath been . . . more professed than laboured, and yet more laboured than advanced; the labour having been, in my judgment, rather in circle than in progression.' —Bacon, loc. cit.

All are acquainted with the biological law that states how the individual, in his development, recapitulates the history of his race. Does not each scientific investigator, in each piece of work he undertakes, recapitulate the process by which human thought has progressed, from its first glimmerings until now; the process by which each Science, and Science herself, has developed? First comes the crude or simple experience, followed by intuitive generalization: then the amplification of this experience by purposive observation—the stage of empirical generalization; and, later, the conscious building up of scientific generalization by logical process. The logical generalization becomes further tested, perhaps by deliberate experiment under the stimulus of secondary hypotheses, and, finally, a still greater induction is achieved which brings the results already obtained into harmonious relation with yet other facts and generalizations, and always with a progressive tendency towards further synthesis.

Now, it is necessary that we realize how, in that making

of knowledge which (in distinction from the knowledge made) is really Science, there are two elements to be distinguished. First, the orderly accumulation of experiences, and, secondly, the coherent symbolic expression of these experiences. The enormous widening of our perceptual field, the enormous increase in our actual and possible experiences, brought about by mechanical means of observation, have led many to speak and to write, perhaps to think, as if Science consisted in the mere accumulation of data, of experiences, of 'facts', and to restrict the application of the phrase 'scientific knowledge' to recorded and assembled experiences. At any rate this is so in Medicine, where there has been a tendency to forget that, without logical inquiry, thought, and generalization, what is gained by experience in the field of disease cannot in itself contribute towards the progress of our *Science*, however useful may be its application in the practice of our *Art*.

It is, perhaps, for this reason that, even to-day, there is some truth (more perhaps than we care to acknowledge), in the words of Bacon that I have just recited. Nothing, I think, in the whole history of Medicine is more striking than the manner in which, during the ages, the same practical results have been repeatedly achieved as a result of the accumulation of similar experiences differently resumed, or, if you will, explained.

Let me give an illustration. We are accustomed, and rightly, to honour the names of Semmelweiss and Lister. Semmelweiss showed us how, under certain circumstances, puerperal fever could be prevented; Lister showed us how, under certain circumstances, operations could be performed with impunity. The results achieved empirically by Semmelweiss are explained for us by reference to the great generalizations of Pasteur, and the practical results achieved by Lister were a consequence of applica-

tion of Pasteur's principles. Countless lives have been saved in the last fifty years as a result of the work of these three great men. But we should be wrong were we to suppose that before the era of Semmelweiss the mortality from puerperal fever was everywhere that which obtained in the hospital at Vienna where Semmelweiss worked. We should be equally wrong were we to suppose that, before the time of Lister, surgical operations were always attended by the terrible consequences that Lister found to exist at the Royal Infirmary at Glasgow. The mortality of puerperal women at Vienna was due to the fact that men of science and of intelligence had discarded what had been known intuitively and empirically long before their day, and that the progress of scientific enthusiasm had driven students to pass from the dissecting-room to the lying-in wards with unwashen hands. Equally, too, surgeons at Glasgow, and elsewhere, fifty or sixty years ago, had forgotten those simple teachings of experience in favour of cleanliness still embodied in the ritual observances of unscientific or uncivilized peoples. It was not until the accumulation, in industrial areas, of unhealthy, of uncleanly and of badly nourished persons had led to the appalling consequences in hospitals with which we are familiar, that forgotten empirical teaching in favour of cleanliness was raised to the higher plane of Science, and the doctrine of asepsis became established. Let us remember that Hippocratic physicians, in the purer air of the isles of Greece, operated under conditions of asepsis which we seek to emulate in London to-day. The surgeons of Pompeii employed knives which would have seemed inelegant to Sir Astley Cooper, but which are now imitated, under the spell of bacteriological commandments, by modern instrument-makers.

Nevertheless, if we seem to return again and again to

the same apparent outlook, it is always from a higher level and each time with a wider sweep of horizon.

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In earliest ages man, when sick, sought to refer the cause of his distress to external agency. He had already learnt to connote cuts, bruises, and broken bones with the activities of hostile men and beasts and with the physical properties of material objects. So, pains and aches must often have seemed to him the consequences of something eaten or drunk, or given him to eat or drink. Later, things found by experience to be noxious, or to which he was obnoxious, were credited with malignity, and he found it easy to ascribe suffering to the malevolent action of some unknown person or, when conscience first pricked him, to the revenge of some one killed—and so to spirits. Places connected with haunting memories, with ambushes, snares, or fatality, were to be avoided as the resort of evil and hostile beings. Thus arose a conception of disease which is expressed to-day when we speak of So-and-So being 'attacked' by influenza, and is implied when medical men announce their intention of 'heading a crusade' to stop the ravages of heart disease or lunacy. Survivals of such ideas are obvious enough when the lunatic explains his illness as due to something that some one has done to him, or to something that some one has put in his food. Such ideas are encouraged—on the level in which they arose—when, to soothe little Tommy who has fallen, Nurse smacks the naughty chair for having hurt poor baby. There was a striking example of a collective delusion of this same nature when four years ago a form of disease known during the centuries reappeared in its due cycle. The elaborate machinery of a Government Department was brought into play to track down the microbes which, it was believed, were being disseminated by enemy action.

However, even in early days, though it was not denied that some places were insalubrious, some foods nocive, and some habits detrimental to well-being, the factor of human 'choice' was admitted and a sense of personal responsibility for personal ill-health and of communal responsibility for communal ill-health rose into consciousness. It became a duty to self and to neighbours to conform to a code or ritual in which was embodied the memories of racial experiences. Such codes first arose at a very early stage of human development. So soon as it became regarded as ethically 'wrong' to infringe the tribal code, and so soon as it was observed that its abrogation was often followed by unpleasant consequences, the idea arose that illness and death were the consequences of moral wrong-doing in nonconformity to the code. The code, becoming divorced from obvious hygienic intention, ultimately ceased to be obviously other than arbitrary or conventional. The wholesome belief, however, that the health of individuals could be preserved by 'right' living (in the tribal sense) must have been from time to time shaken, and its force weakened, by the irruption of those secular pestilences we still experience; and so, to meet the case, it was suggested that such pestilences were a manifestation of Divine wrath at the iniquity of mankind in general or of particular communities.

We must admit that the theory of the Divine, or at least 'celestial', causation of epidemics implies recognition of three very important facts: (1) that the observance of the rules of health by individuals does not necessarily secure those individuals from pestilence; (2) that epidemics and pestilences are disorders of communal health rather than disorders of the health of individuals, however numerous; and (3) that the ultimate causes of all great pestilences must be sought for amongst the primary

factors controlling and affecting all life, however symbolized, and whatever the conjunct conditions modifying the reactions of mankind to these primary factors or agents.

Thus Hippocrates, the first and greatest of physicians, not only recognized the duty of each one of us in respect of healthy living, but, as epidemiologist, inferred the incursion into human affairs, however wisely ordered, of the cosmic, celestial, or Divine factor. Our *répertoire* of facts and experiences is infinitely greater than that of Hippocrates; but, the more carefully we generalize from each addition to our knowledge gained by observation in the hospital, in the laboratory, and in the field, the more acutely are we impelled to adopt his standpoint. Those who to-day are of his School observe what happens and think in terms of experience: they describe what is seen in persons and in communities: they consider the relation of the happenings both to personal activities and to extra-corporeal agencies; they advise not only how to live, but to what end. As metaphysicians they are conceptualists rather than realists, as physicians they are vitalist rather than materialist, and as philosophers they would pursue the chain of causation to its origin in the infinitely unknown.

But there was, in the time of Hippocrates, another School, that of Cnidus, which was later represented in essential respects by that of Galen. Galen himself based his philosophy upon a form of Platonic realism that later drifted into the realism of the mediaeval scholastics. Galenists of to-day still deal with diseases as scholastic, if not material realities, and take, as their fixed point of departure for reasoning, not their clinical experiences, but their universals, or formal concepts. They seek to demonstrate 'diseases' in the laboratory and in the post-mortem room, ignoring the primary

disturbance of function in patients, and insisting rather on the consequent organic changes. To an Hippocratic physician diagnosis has always meant the recognition (i) of the whole disorder of function present to the individual, (ii) of the whole complex of its causation, and (iii) of the whole series of its consequences. To the Galenists of the past and of to-day diagnosis means the reference of the patient's illness to some formally recognized concept which is regarded as a philosophic reality. Thus do they place themselves in line of descent—though, of course, of long descent—from the primitive peoples who personify forms of disease by particular demons.

In the sixteenth century, after the downfall in theology of that scholastic realism which earlier went hand-in-hand with a certain kind of superstition, with the neglect of hygiene, and with the invocation of the protection of saints, there was a great revival of Hippocratic medicine by sundry physicians, to whom justice has hardly yet been done. Later still, Sydenham, following Guillaume de Baillou, popularized the Hippocratic notion of epidemics as the expression of the reaction of peoples to certain forces or conditions of life, of telluric or cosmic origin. But otherwise he reverted to scholastic realism, teaching that diseases are to be classified, as are the plants and flowers of the field. Thus Sydenham set the fashion for the many vain attempts made, by botanical physicians such as Linnaeus and Cullen during the eighteenth century, to deal with diseases as if existing apart from the persons affected, and dowered with a substance real in the Platonic sense, if not material in ours.

Now, great as have been the formal advantages of analysis, of attempts at classification, and so forth, the great drawbacks of adherence to what I will here call 'scholasticism' in medicine have been the limitations

imposed upon our recognition of the complexity of causation of disease: the disregard implied for personal responsibility; and the tendency to pursue specific remedies for particular diseases, rather than the study of the personal condition of each sick person. Over and above all this, it has encouraged deduction from concepts rather than induction from experience, the investigation of hypostatized 'diseases' rather than of *what happens*. Lastly, the modern scholastics insist on regarding State medicine as concerned with mere aggregations of *cases* of disease rather than with disorders of the health of communities as such. To adopt words which Bacon used in another connotation, State medicine should deal with 'man congregate or in society'. It may be said of the modern scholastic physician that he 'considereth man segregate or distributively'. He therefore proceeds to 'stamp out' the epidemic by isolating or inoculating individual persons, and there is a tendency to neglect the study of the conditions under which epidemics occur, and the order of their happenings.

During the early part of the last century an extremely materialistic school of thought obscured, for the moment, the great conclusions of the Science of Medicine, while the patient observations of its adherents greatly advanced our wealth in facts. I refer to the great morbid anatomists, and particularly those of France. They had found the classifications (based upon symptomatology) of the botanical physicians of the eighteenth century inconsistent with observations made on changes found in the post-mortem room. The notion then arose that in these changes we had at last met with the true 'substantia' of disease—with that which, in Galen's sense, follows the symptoms as does the substance follow the shadow. Thus arose the doctrine of the specificity of disease, so tenaciously adhered to to-day—the doctrine that each

disease is specific, and is manifested by specific structural changes.

The fallacy that the substance of disease is to be found in organic changes still persists, and is attended by certain consequences worth considering. It leads to the consideration of sick persons as suffering from organic changes in this, that, or the other organ, rather than from dissociation of the functional unity of the whole body, and thus induces a deplorable extension of specialism and an often unjustifiable optimism in respect of certain surgical procedures. Moreover, it involves a slighting depreciation of those disorders of function now recognized as the 'beginnings of disease'. It minimizes at all times the importance of forms of ill-health not demonstrably accompanied in the upshot by evidence of organic change. There is a story of a fair American who consulted an eminent physician. After a careful examination the sage thus delivered himself: 'Madam, I am happy to assure you that you have no disease. Your trouble is purely functional.' And she replied, with some spirit, 'You don't say, Doc! Then I guess I function pretty badly.' To-day, however, largely owing to the influence of Sir James Mackenzie and others, a reaction is setting in against such tendencies; a reaction which, in its turn, has its dangers and may be pursued too far.

Some seventy or eighty years ago, however, while physicians were still mostly occupied with the study of the organic changes of disease as seen in individuals, a great School of Sanitarians arose (headed by Chadwick, himself not a doctor) that found, in the vigour of men's lives, their best defence against disease. That school initiated vast schemes for the improvement of the conditions which had arisen as a consequence of our industrial expansion.

Of the practical value of the work of these men it is impossible to speak too highly; nevertheless, under their influence, the Hippocratic epidemiology fell completely into oblivion. Later, when it was found that not even drains, a main water-supply, and pure food and drink always prevent epidemic disease, the rise of bacteriology gave encouragement to others, who spoke contemptuously of Chadwick and his followers as inculcating hygiene by whitewash. The bacteriologists soon caused it to be accepted that the morphological and cultural characters of microbes are invariable and specific, and that their onslaughts necessarily evoke specific symptoms and the appearance of specific morbid changes. So a new and healthy world was to be brought about by antiseptics and universal protective inoculation. Indeed, the classification of disease by specific morbid changes having been found in the long run as little satisfactory as the earlier classifications made by the botanical physicians, diseases were to be finally classified by the specific microbes associated with them.

Now we must not for one moment under-value the enormous number of facts given to us by the bacteriologists, and the incalculable help that applied bacteriology has brought to the art of medicine. Yet it is odd that, at the very moment when biologists, under the influence of the theory of evolution, were everywhere approaching the facts of life in a new spirit, the bacteriologists should have set up the most rigid of barriers between the species into which they divided the objects of their investigations. Moreover, if the great Sanitarians had stressed unduly the importance of the 'soil', the bacteriologists forgot all but the 'seed'. Neither party cared to remember the third or Hippocratic factor! Yet, whether we think of 'man distributively' or 'man congregate', no conjunction of 'seed' and 'soil' appears effective to

produce pestilence except on due season or occasion, hard though it be for us to express more definitely all that our experiences lead us to suggest by this phrase.

The world-wide pestilence of 1918, which we call influenza, has, however, confounded the rigid bacteriologists as completely as did the influenza of 1889 confound the advocates of drainage and whitewash. We are again forced to consider the importance of the observations which in times past led men to the expression of belief in the cosmic origin of pandemics.

Such is, perhaps, the present and interesting position that we have reached. It seems as if we are about to recognize the purely relative importance of the 'single cause' in respect of the evocation of disease. We are beginning to see that the type of reaction in each individual or in each community varies not only with the state of the subject and with the environmental conditions, but with the incursion of factors which do not as yet come within our perceptual field, though it must of course be admitted that for different types of disorder and pestilence, different etiological values must be allotted to each of these elements in the production of disease.

Again—and here Medicine, after centuries, is groping her way towards reunion with Science and Philosophy in general—we are beginning to recognize that when we discuss Science and Health we must have in mind, not merely individuals, but higher units—communities, nations, and leagues of nations—not mere masses of individuals, but collectivities, with collective function and subject to collective disorder. Finally, we are recognizing that the sterile accumulation of mere facts is not greatly helping us; that our task is to bring these facts together, to find some general synthetic expression for them, agreeing even so that our generalizations are

only of symbolic value, and are liable to readjustment, as knowledge accrues. The moment we attach positive value to our generalizations we relapse into formal and academic *System* : deduction and analysis alone then remain to us as intellectual tools.

Once more (and this time in the words of Oliver Wendell Holmes) let us admit that 'disease is a function and not an entity'. Using the word in the mathematical rather than the physiological sense, it is a function of the living organism, given certain conditions.

§ 3. *The Scientific Problem*

'It is no other method than that which brute beasts are capable of, and do put in use; which is a perpetual understanding or practising some one thing, urged and imposed by an absolute necessity of conservation of being.'—Bacon, loc. cit.

The change of outlook in Medicine that we have indicated is consequent, though not too closely, upon a change that has, during the last thirty or forty years, taken place in biology. That change has had more than one root. Thus, following the work of Roux, who though nominally mechanistic has yet given an enormous impulse to vitalism, there has been a revival of the old synthetic and functional thought of Aristotle, Bichat, and Cuvier. On the other there has been a drifting away from pure Darwinism and a reversion to Lamarck, of which the early prophet was Samuel Butler.

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Roux held that living things persist, in spite of their metabolism, in spite, also, of concurrent changes of environment, by reason of their power of self-regulation. Now a neo-Vitalist will proceed a little farther, and will think of living things primarily as units of functional organization. He will then find special kinds of functional activity, and special modes of response to stimulus, to be

proper to special kinds of organization units. But biologists of all Schools, whatever their philosophical peculiarities, agree in distinguishing two kinds of function as common to and exercised by all living units. Of these one, which we may call the animal or outer function, regulates and secures the adjustment of the unit to its environment. The other, more primitive, and therefore more stable, which we may call vegetative or inner, is concerned with the regulation of the internal life of the organism or unit; with its nutrition, and with its reproduction. The visible structure of a cell, or of an organ, or of an organ-complex, depends therefore upon, and is primarily an expression of, the manner in which the inner functions of the cell, organ, or complex are carried out or co-ordinated. The organic changes that some call disease are the *consequences* of the dissociation of inner or vegetable functions entailed, perhaps, by failure of due adjustment of external relations. They do not represent something superimposed from outside and, so to speak, invading the organization unit. If we apply this biological conception to, let us say, cancer, we realize that 'the disease' is not the mass removed, or removable, by the surgeon's knife, but a disorder or degradation of certain functional activities that permits irregular, aberrant, and reversionary forms of reproduction on the part of certain elements in the body complex, which thus uncontrolled—and to use a common simile 'rebellious'—disorganize the whole 'system'.

In different cases this degradation or reversion is, in different proportions, an expression (1) of weakened co-ordination of the elements making up the whole body, and (2) of local failure under stress of local irritation or injury. The political analogy is perfectly just. Responsibility for rebellion is distributed between imperfect or faulty central control and peculiar or exasperating local

conditions. And in disease, as in politics, the stronger the central control and the more purely local the irritating cause, the greater the chances of restoration. But, when feebleness of the central government leads to disintegration at the periphery, force, or the knife, is no remedy; and the inevitable process of dissolution proceeds. Even when disease is definitely associated with the presence of micro-organisms or the grosser parasites, the elements of central vigour and control cannot be neglected. The invader finds no foothold when the defences are well organized: he flourishes when these are constitutionally weak or temporarily inadequate.

Whilst, however, such is the general rule, we must not forget that the human body is from time to time subjected to the influence of certain changes in environment which occur too rarely in a generation for the perpetuation of efficient organization against them. Just so, however stable, however well-conducted, the government of a political unit may seem, yet the intervention of famine or of physical disaster may provoke revolution and disintegration of central and local control.

Now the natural method of securing a healthy race is, as Bacon saw, the slow process of adjustment by response to stimulus continued throughout the ages. But we, men and women, have the power, which we believe denied to the brutes, of conscious response or of *choice* in response. Nature's response, therefore, can be accelerated or retarded by the intervention of human activity, of human volition. And let it be remembered that human volition can not merely decide, within certain limits, the response to external conditions, but can in many instances directly modify these conditions themselves, and so obviate the need for individual or racial adaptation to them. Hence the enormous complexity of this problem of Science and Health, and the danger lest,

in acting as we think kindly from the point of view of this or that individual, we may be acting unwisely in the interests of the greater complexes.

Superficially, of course, it would seem that, just as it has been a biological convention to consider the cell as the simplest unit of function, so is it proper to consider the human body (itself composed of associated and co-ordinated organs and tissues; themselves complexes of lesser cell systems) as the highest and most differentiated unit in a biological sense. But we must by no means be content thus to restrict our range of biological conception. On the one hand, though it is true that our positive knowledge as yet hardly extends below the grade of such simple organisms as bacteria, yet we have some form of acquaintance with what are called 'filter-passers'; with some viruses that are less than cells, if indeed they are particulate. Dixon has suggested that viruses of this nature may be ferment-units which are parasitic, so to speak, to bacteria themselves; that may be carried by bacteria, as we carry grosser parasites; thus justifying *old* Samuel Butler's doggerel.

While we are thus compelled to extend the scale of life in the direction of the infinitely little, no mere human pride should lead us to forget that you and I are components of biological units far more complex than ourselves, to which we stand, perhaps, in the same relation as do our separate blood corpuscles to what we call ourselves. Individual persons do not, biologically, represent the most complex of organization units. The pregnant woman, the mother and suckling, the family, the tribe, the race, the nation, the League of Nations, and humanity itself: each is a complex organization unit in the biological sense, whereof each component has personal functions, as well as relations to and dependence on those with which it is associated. Each individual who

walks the earth is biologically a part of the one great existing human unit, but is also a part of, is physically linked with, and represents in himself, those individuals who have gone before and those who will follow. How infinitely small, therefore, are the responsibilities of each of us in respect of what we deem ourselves, when compared with the responsibilities we owe to those with whom we are associated! And these responsibilities are not less than is the debt we owe to those by virtue of whose efforts we are endowed with the powers that we do possess.

The individual components of such a high function complex as a community may not seem to us so closely associated in a material sense as are the organs or cells of the body of each one of us, or as are even the mother and her unborn, or newly-born, child. Nevertheless, the association of interdependent functional activity exists. The real thing in organization is not form but activity. It is association in the exercise of function rather than mere physical continuity that we must consider. And so, just as Medicine, in being concerned with the disorders of health in persons, has to take note of maladjustments between the functions of the component organs and tissues of the human body, so in the art of government has note to be taken of disorders and maladjustments between the component individuals of communities, and State Medicine is not so much concerned with the disorders of health of persons in a community considered separately as with the disorder of health of the community itself.

Here the word 'health' is used primarily with the physical connotation, but we are well persuaded that disorders of the mental health of a community cannot be easily excluded from the purview of the epidemiologist. Certainly the so-called epidemic manias and psychoses

of the Middle Ages were, like many of the mental phases manifested during the late War, closely associated, temporally and geographically, with widespread disorders of physical health.

We may turn now to a brief consideration of the influence, in respect of Science and Health, of some of the factors that have been particularly dealt with by Samuel Butler and those who to-day are referred to as neo-Lamarckians. If the appropriate adaptive response to external stimulus is, for an individual or for a race, only organized as a result of experience, then the presentation of new stimuli will always, at first, be provocative of disorder that can only be overcome by practice in responsive effort. We may, by human intervention, be able sometimes to prevent the recurrence of the same change in environment, but not always; and we shall never be able to prevent the occurrence of new kinds of changes unless—which is unthinkable—we can stabilize the universe. We must remember, too, that unless provocative stimulus recurs, individuals and races alike lose their power of adaptation to, or their protection against, that kind of stimulus. So that, in general terms, our hope is for the acquisition by the race of powers of adaptation to all likely forms of stimulation, and for the retention of all powers of adaptive response acquired to all forms of stimulus within human experience. It therefore becomes of the very greatest importance to those who take a wide view of our responsibilities in respect of the public health, to appreciate all that is involved, or implied, by the word heredity.

We demand therefore: How may powers of response acquired by the individual be preserved for the race; how may the race be prevented from losing what has been acquired, or is acquired, by individuals?

In the past, physicians, like biologists in general, have

thought of heredity simply in terms of the transmission of form. Now, while it would be wrong to consider the question merely in terms of function, or functional aptitudes, there is nevertheless an intricate relationship between the exercise of function and the appearance of form, and between the degradation of functional aptitudes and degeneration in form, not only for individuals but for races. Jeremiah expresses more perfectly than do the neo-Lamarckians, the position in respect of these problems: 'The fathers have eaten a sour grape, and the children's teeth are set on edge.'

Let us consider the matter a little more closely. Modern biology considers that not form but functional activity is the really important thing in organization, just as Goethe saw that 'fixed form' is only a momentary phase of 'form change', and 'form change' itself chiefly of interest as the manifestation of functional activity. The physician, however, largely concerned with development of individuals, has to recognize that, in certain cases, what we call congenital disease is an expression of defect in form and in organization of function which do not permit of the normal response to normal stimuli. As a matter of fact, for each individual there are two stages of development. During the later stage (according to Roux and those who follow him), development of form follows the exercise of functional activity; that is to say, it is a result of *personal* effort. But in the earlier period, form is elaborated in anticipation of the functional activity that may one day be associated with it. If we translate these biological generalizations into popular terms, do we not at once realize their validity? Do we not see personal advantages due to parental effort tending to confer an advantageous start in life upon offspring, a start which becomes increasingly valuable for one or two generations, but of which the benefit is lost if there be not the

continued exercise of voluntary effort to make use of opportunities on the part of those on whom advantage is conferred?

Functional activity, we may therefore say, determines form; not only for the individual but increasingly for the race. If, however, parental responsibility is thus emphasized, it is no less the fact that the responsibility is stressed of each one of us for the use of the aptitudes in form and in organization handed down to us by our predecessors.

There may well be failure by any particular individual or community, but ultimate adjustment will be effected by the continuing efforts of the successors of that individual or community, all the more successfully by reason of those originally made. This is why, in the interests of the race, it is better that we insist on the need for personal *effort* than on that for passive *protection*.

§ 4. *The Human Standpoint*

'To speak, therefore, of Medicine, and to resume that we have said, ascending a little higher.'—BACON, loc. cit.

So far we have discussed firstly the origin and development of our notions concerning disease, and, secondly, some of those teachings of modern biology that seem destined to exercise influence upon our plans for the prevention of disease. What now is the outlook from the completely human standpoint?

Unless there be full appreciation of the fundamental principles involved, many superficially attractive schemes for the prevention of disease are bound to entail disappointment and may, indeed, prove wasteful, if not ultimately mischievous. But it is idle to deny that the promulgation of such schemes is more popular than the examination of the principles on which action should be

founded. The note of criticism, or at least of restraint from uncritical enthusiasm, will always expose to the charge of pessimism or of *laisser-faire*. Public memory is very short; but it may be recalled that during the last twenty-five years we have seen the inception of campaigns against many diseases, all directed by the noblest aims, but rarely by sound principles. Cancer, tuberculosis, syphilis, infantile mortality, and lunacy have in turn been the object, as it is said, of systematic attack. Yet the mortality from cancer is increasing, and the cure of cancer is as far away as ever: the incidence of tuberculosis is again rising; venereal disease is more widely diffused than ever. The diminution in infantile mortality is more than balanced by the fall of the birth-rate, and if to-day the lunatic asylums are less full than formerly, it is, in part, because during the war the death-rate in asylums soared to an unappreciated height. The last pandemic of influenza levied a toll of which the gravity is not yet appreciated by a nation whose sensitiveness has become blunted, and in the wake of this pandemic has followed a trail of old foes with new faces, or with new names, which we are sometimes told are new diseases. Surely it is high time that we seriously considered practical proposals in the light of first principles.

In the first place, let us frankly admit that, unless existing conditions be standardized and progress suspended, disease in general can never be reduced to vanishing-point, since every change in environmental conditions must involve the need for fresh adjustments which to many will be difficult and for some impossible. As well might we expect the rising tide not to break into surf at its advancing edge, as that disease should disappear from a community that is undergoing progressive organization! Moreover, even if we were able to remove all rocks from the shores against which the waves

of progress break, we could not expect to establish immunity from those recurrent disturbances, dependent on factors beyond man's control, which, from time to time, throw our social system into disorder; even as tidal waves agitate sometimes the smoothest of oceans.

Still, this is not to say that we may not, in some measure, mitigate the rigours of the rocky coast; put up breakwaters here and there, and construct harbours of refuge where the tides may rise peacefully during even the severest storms. But we must consider our plans at least as carefully as does the civil engineer in his own sphere of action; above all, we must not be led away by mere sentiment. Certainly we should attempt to distinguish critically between action in respect of individuals and of communities. Communities are social complexes that are not yet fully organized: the component individuals and groups of individuals are not yet so conscious of their interdependence as they may one day be: as they must be if organization of function is to be perfected. But it is idle to maintain that by improving the health or alleviating the sickness of particular individuals we necessarily benefit the community as a whole. This is a hard saying, but no paradox. The health of the whole collectivity may require, and often does require, the subordination of the interests of individual parts. Just so, the health of the body-personal may require the sacrifice rather than the preservation of an organ or a limb

As a matter of fact there is an extent to which the methods and application of Medicine, although of immediate benefit to many individuals who are actually suffering, must and do tend to lower the average level of health and the adaptability of the race, ultimately increasing the number of persons who are sickly and feeble. For no gain is transmitted that is not acquired

by the effort of the organism; and no gain that is passively accepted is preserved by the race; whilst the propagation of a weaker stock is favoured in proportion to the number of weaklings saved by art. The expensive care of the insane, the tuberculous, the deformed, and the indigent, tends, moreover, to impose a restrictive disability upon those who, if not fettered by taxation, would be capable of effort advantageous to themselves, to their families, and to the State.

I do not suggest that we should hang petty criminals by batches, allow the insane to perish miserably, and make no effort to prolong the lives of the tuberculous. I no more suggest *that*, than do I propose that the Red Cross be abolished in order that the next war be brief. The fulfilment of the moral duty that we instinctively feel incumbent on us is in itself not the least important of the necessary stages in the toilsome path of human ascent. But, beyond our present duty to the individual straggler from the ranks, there is the still higher aim of so organizing communal, national, and international life that the stragglers are few and that their needs may be satisfied without hampering the advance of the whole army. At present there is real danger lest uncritical sympathy for, and injudicious aid to, the individual should entail harm to the community and the race. Nature—the 'cosmic process'—settles many problems far better than we do. If the epileptic and imbecile, or weak-minded, are left to themselves, they marry amongst their kind, and the consequent and inexorable exaggeration of hereditary defect then puts an end to the stock. Yet we continually speak as if such inter-marriage would produce a race of epileptics or imbeciles. The very contrary is the fact; and human interference seems often doomed to perpetuate the very evils that it is designed to prevent.

Again, it is pretty certain that the personal profit to

the individual from the responsive effort of the body to carry out a defensive reaction against microbic infection is transmitted to offspring on favourable terms. Racial immunity to tuberculosis will probably be finally achieved, if at all, by the transmission to offspring of properties acquired by victorious reactions in early life. But passive protection not only from certain forms of bacillary invasion, but from personal discomfort or difficulty, is something which must be paid for by increased susceptibility to functional disorder under what should be useful stimulus. I am not sure, indeed, that as a nation we have not recently paid, and are not still paying, for the sheltered life led by so many during the last thirty years. Life had become for many too easy. And the true secret seems to lie in the conscious adoption by individuals and by communities of the great lesson to be learnt from Nature and Science alike. It is as true in matters of health as otherwise, that God helps those who help themselves; and the message of Longfellow's *Psalm of Life* is as practical as it is unfashionable.

It has been my experience, during the last twenty-five years, to have treated many thousands of patients at many of our great hospitals, and it is my conviction that there are few cases of disease to be seen at these places which would have occurred had there not been, on the part of the patient or his immediate progenitors, some lack of patient persistence in right and ordered habits of physical, mental, and moral life. Sir George Newman, in a recent Memorandum, lays greater stress, I think, than any one hitherto on the ultimate importance, in the production of grave disorders of the stomach and bowels, of lack of attention to such habits of cleanliness, or care in eating, of regularity and so forth, as can only be acquired in childhood by upbringing and effort.

Yet nothing is more deplorable than the resort to our

hospitals of young men and women, painfully eager for a diagnosis and a remedy, who, by spending less than they do on an evening's amusement at the 'Pictures', could acquire a tooth-brush, a sufficiency of Epsom Salts, and perfect health. All sense of personal responsibility is lacking to these people; there are diseases, they think; there are doctors and drugs to be had for nothing; why, then, fag? If they achieve parenthood, their children, lacking impetus, grow up even less sufficiently organized than the parents in respect of aptitude for the performance of natural functions, and are ready subjects for the remedial knife of the surgeon, since the parental failure in function has entailed structural under-development on the part of the children. Herein is some explanation of the increasing frequency with which we meet certain minor defects which are the background of graver disorders.

Again: circumstances have made it easy and convenient for mothers during the last thirty years to exempt themselves from the duty of suckling their own babies. The biological consequences are already obvious. Amongst young mothers of to-day there is diminished capacity; the breast is becoming a functionless structure. At the same time, the necessity thus imposed for the artificial rearing of infants is, in its turn, entailing as its penalty an increasing feebleness in infantile powers of resistance, an increasing poverty of structure, and an increasing need for protection. The habit of artificial restriction of the birth-rate is already entailing for the newer generation a definitely impaired capacity for parenthood, and an extraordinary sign of the times is the supply of little books, written by enthusiastic authoresses, giving instruction in the performance of what should be for a healthy couple a perfectly natural and spontaneous function. The fact is that, as Butler might have put it,

racial memories are becoming lost or confused by reason of the avoidance of recapitulative or repetitive personal effort, and racial adaptations of form and function are in real danger of being lost to the race.

From another point of view, it is of no advantage that we 'suppress' certain special diseases by methods of artificial protection, if there be, at the same time, a general reduction in, not merely the physical but the mental and moral vigour of men's lives. It will prove equally futile to suppress alcoholism by preventing the consumption of alcohol, so long as the invertebrate flabbiness of the potential drunkard is tacitly encouraged, is freely reproduced, and is allowed to form the foundation of other physical vices.

But how many of those who clamour for battle to be waged against this, that, or the other enemy of the human race would care to support a measure imposing, for the neglect of personal health, even such a moderate penalty as "five shillings or a week"? Yet it is no exaggeration to say that half the money expended by our voluntary and rate-supported hospitals, and half the time given, without recompense, by doctors, would be immediately saved were it not for the neglect of soap-and-water, the tooth-brush, and those racial promptings that are faithfully obeyed by the domestic cat and dog. In fact, our resources, which were never in greater need of conservation, are frittered away as a result of false conceptions of disease held by sentimentalists, who hesitate to inculcate personal responsibility for the right training of self and of offspring and for the preservation of personal health.

But to recognize this is not enough. The idea is still prevalent, even amongst those who, in this country, profess communism, that in this matter of public health the reciprocity should be, as the Irishman said, 'all on one side,' and *that* side that of the other party to the

bargain. The idea that the responsibility for the health of a borough should rest upon the local Medical Officer of Health, and for that of the Nation upon the shoulders of demigods at Whitehall, is as dangerous as the idea that doctors should be paid to keep individuals well. The Ministry of Health, the local Medical Officer, and the plain doctor may each and all direct measures for the restoration of health to the organized units with which they are immediately concerned, and may give useful counsel with a view to the avoidance of disease. But the responsibility and the real work must be shared.

We saw and learnt during the crises of the war what could be accomplished by concerted effort and restraint, when all helped and tried to help in their measure and under moderately intelligent direction. As much could be done to mitigate the consequences of pestilence during times of pestilence as was done for war during war; and as much could be done in normal times to fortify against pestilence as can be done during peace to lessen the possibility of war, or to restrict its conflagrations when its prevention is found impossible. The only practical way of mitigating plagues lies in applying the lessons of biology, in utilizing the memories of racial experience, and in developing the sense of need for common action for the preservation of the common health.

The farther we proceed then, the clearer does it become that health is not a matter for specialists and cannot be divorced from sociology and from politics. War, famine, and pestilence ever march side by side. We all consider wars to be productive of pestilence; and it is true that just as some harmful parasites are killed by the poisons they produce, so wars, the begetters of pestilence, are ended by their own products, if Science does not intervene. It is certain that the influenza of 1918 modified, in no small degree, the resistance, the moral, and the

energies of civil and military populations. As much may be said of the dearth which, though largely artificial and epiphenomenal, was not, I think, altogether unconnected with the general conditions that even in peace time sometimes affect the earth's productiveness. Indeed some would regard war, dearth, and pestilence as each and all dependent on the remoter influences affecting all forms of life, the 'divine something', if you will, of Hippocrates. Speaking purely from the standpoint of experience, I am not sure that they are wrong.

It is, however, clear, that no efforts directed against the spread of the generalized disorders of health we call pestilence and plague go near the root of the matter, so long as the production of the earth's fruits and their adequate distribution to the world's populations are allowed, by the intervention of war, to fall below the optimum. Nor is the influence of war on the grand scale —if grand be the adjective—confined, in respect of health, to the propagation of pestilence. The effects of stress, of under-feeding, and of anxiety, fall upon the children unto the third and fourth generation of even those who walk in the way of physiological righteousness. The loss by death of the finest prospective fathers, the infection by disease of too many who escape death or mutilation, the arrest of the orderly development of the immature, all these are consequences more important to the race than are the mutilations and amputations sustained by those who deservedly obtain our commiseration. And can we forget the deprivation of legitimate opportunity for motherhood, and the psychical and social consequences of this deprivation?

Perhaps I am now about to exceed my province, but I confess that it was with feelings which I find some difficulty in describing that I recently read the able, eloquent, and comprehensive Memorandum on National

Health, written by the Chief Medical Officer of the Ministry of Health, and found therein not one direct allusion to the most potently injurious set of conditions affecting the national health: I mean, international warfare. I fully recognize the limitations imposed upon a Government official; but does not the very existence of these limitations reduce our talk about national concern for health to a rather sorry farce? If we cover our country, from John o' Groats' to Land's End, with the most perfect web of sanitary organization and mechanism; if we notify every conceivable disease and segregate every possible carrier of microbes; if we set half the population to lecture and inspect the other half, and continue our efforts for a generation; even then we shall not achieve anything that will not be destroyed by six months of war involving the organization of a nation in arms. And yet how much could be done in six months were each one of us to do his best, with conscious effort, to improve his own functional organization and physical condition by prosecuting the endeavours and obeying the rules that the experience of mankind has tested throughout the ages!

And something more. If every one were to recognize his own share of responsibility for the health of the community to which he belongs, and every community to recognize its own share of responsibility for the general well-being, then the world would have advanced immeasurably towards successful adaptation to, and the control, if not the subjection, of many of the forces we represent as playing on it. Progressive functional organization links the amoeba serially with man. Progressive functional organization has brought each of us from the form of a tiny unicellular organism to what we are. Progressive functional organization will secure us, so far as is possible, against war, against famine, and against

disease; if, that is, the necessary effort in progressive organization is consciously pursued and maintained.

But is there any definite end to this process of progressive effort? Shall we ever attain the summit which seems to elude us, as one mountain peak rises behind another? I do not say that mankind will ever attain perfect adjustment in progress, but that I think is not the point. It is our duty to continue: and I would rather be the efficient donkey trotting behind the elusive carrot dangled by his driver, than would I be his stall-fed brother living in petty idleness. At any rate, although a measure of choice is held out to us, we are not free from responsibility. Telemachus may fulfil his duty in the ordered quiet of his little island where—

> . . . 'centred in the sphere
> Of common duties, decent not to fail'

he may succeed in keeping out disease for a time. But even in the best ordered of little islands comfort will beget sloth, and catastrophe, when it comes, will find a people weak and ill-prepared. If, on the other hand, like Ulysses, we are resolved to

> 'Push off, and sitting well in order smite
> The sounding furrows'

our spirits

> 'yearning in desire
> To follow knowledge like a sinking star,
> Beyond the utmost bound of human thought'

equally may we meet with hazard, with accident, or with catastrophe. But we shall be fulfilling the duty which we know is imposed upon us—

> 'To strive, to seek, to find, and not to yield.'

In so doing we shall tread the pathway of Science to moral, mental, and physical Health.

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XI

SCIENCE AND RELIGION

JULIAN S. HUXLEY

'THE next great task of Science is to create a religion for humanity.' So says Lord Morley in one of his essays. It is a striking saying, coming as it does from one in whom thought and action have been so intertwined, one to whom reason, not dogma, is the basis of morality, achievement, not emotion, its justification.

Let those words be my encouragement; for they challenge at the outset, and to my mind rightly, two of the most persistent difficulties that confront one who tries to write of the relations between Science and Religion. The man of science too often asks what science can have to do with what he brands as utterly and wholly unscientific; the religiously-minded man demands what gain can follow from contact with the cold and inhuman attitude of pure reason. To those questions I hope that this lecture will provide a partial answer. Meanwhile I shall begin with a perhaps less ultimate but more pressing question. That question is asked by many men and women to-day, who on the one hand feel as it were instinctively that religion of some sort is necessary for life, yet on the other are unable to do violence to their intellectual selves by denying the facts that reason and scientific inquiry reveal, or by closing their eyes to them.

The question, in briefest form, is this: 'What room does science leave for God?'

To the savage, all is spirit. The meanest objects are

charged with influence, the commonest actions fraught with spiritual possibilities, the operations of nature one and all are brought about by spiritual powers. But with ordered civilization and dispassionate observation, a network of material cause and effect invades this spiritual domain. The mysterious influences, for example, believed to be inherent in springs and running rivers became personified, and, anthropomorphized as nymphs or gods, were removed into a seclusion more remote from practical and everyday life than their unpersonified predecessors. Later, they retreated still farther from actuality into a half-believed mythology, and then passed away into the powerlessness of avowed fairy-story or literary symbolism, while the rivers, perceived as the resultant of natural forces, were more and more harnessed to man's use. So with the wind and the rain, the growth of crops, the storms of the sea. So, in due time, with the thunder and the lightning, with earthquakes, eruptions, comets, eclipses, pestilences.

This process of liberating matter from arbitrary and mysterious power, of perceiving it as orderly and endowed with regularity of natural law, of bringing it more and more beneath human control, was, on the other hand, accompanied by what may be called a combined condensation and sublimation of the spiritual forces accepted by human faith, from spirit to spirits, spirits to gods, gods to God. But now it seems as if this condensation had reached its limit, and the sublimation could only go farther by resolving the one God into an empty name or the vaguest unreality.

No one who has read Flaubert's *Tentation de St. Antoine* can forget the procession of gods, hundreds upon hundreds, in every diversity of form, all the divinities of early man, defiling past the visionary saint to tumble into the abyss and be for ever destroyed. Is it to be so

with every God? Is God only a personified symbol of our residuum of ignorance? Is to hold the idea of God in any form to be, as Salomon Reinach believes, in an infantile stage of human development, and must we with him define religion as 'a sum of beliefs impeding the free use of human faculty'?

I think not; and I shall endeavour to justify my belief to you to-day, and to show that, albeit much alteration and a thorough revision of ideas is needed, the term *God* has an important scientific connotation, and further that the present stagnation of religion can be remedied, if, as has happened again and again in biological evolution, the old forms become extinct or subordinate, and a new dominant type is developed along quite fresh lines.

In any case the man of science must obviously, if he face the problem at all, take up a scientific attitude of mind towards it. He cannot say that there is no such thing as religion; or try to whittle it away by explaining that it is something else—a complicated fear, or a sublimated sex-instinct, or a combination of credulity and duplicity. A thing, if it is a thing at all, is never merely something else. Nor can he submit to the pretensions of those who assert that it is too sacred to be touched, or that its certainties are greater than those of science. No—he must treat it for what it is—a fact, and a very important fact at that, in human history: and he must see whether the application of scientific method to its study—in other words, its illumination by the faculty of pure intellect—will help not only our comprehension of religion in the past, but its actual development in the future.

He can study it in various ways. He can use the method of observation and comparison, collecting and collating facts until he is able to give a connected account

of the manifestations of religion and of their past history; he can study it physiologically, so to speak, to see what part it plays in the body politic, and how that part may alter with circumstances; or he may seek to investigate its essence, to discover not only how it appears and what it does, but what it *is*.

Further, he must have some general principles to lean on in his search, principles both positive and negative. He must be content to leave certain possibilities out of account because as yet he cannot see how they can be connected with his organized scheme of things; in other words, he has to be content to build slowly and imperfectly in order that he may be sure of building soundly. This is the principle which we may call positive agnosticism.

This very fact has been in the past one of the great obstacles in the way of successful treatment of religion by science. One of the attributes of man is his desire for a complete explanation, or at least a complete view, of his universe, and this has been at the bottom of much doctrine and many creeds. But before Kepler and Newton, no sort of scientific account could be given of celestial phenomena; before Darwin, none of Natural History; before the recent revival in psychology, none of the mind and its workings. In the second half of the nineteenth century, for instance, science could give an adequate account of most inorganic phenomena, and, in broad outline, of evolutionary geology and biology; but mind was still refractory. Accordingly, the philosophy of science was mainly materialist. But the common man felt that mind was not the empty epiphenomenon that orthodox science would have it; and he desired a scheme of things in which mind should be more adequately explained than it could be by science at its then stage of development. *Hinc illae lacrimae.*

To-day, it is at least possible to link up, not only physics and chemistry and geology and evolutionary biology, but also anthropology and psychology, into a whole which, though far from complete, is at least organized and coherent with itself. If the seventeenth century cleared the ground for that dwelling-place of human mind which we call the scientific view of things, if the eighteenth century laid the foundations and the nineteenth built the walls, the twentieth is already fitting up some of the rooms for actual habitation.

There are certain other domains of reality which have not yet been properly investigated by science. Telepathy, for instance, and the whole mass of phenomenon included broadly under the term spiritualism, are in about the same position with regard to organized scientific thought to-day as was astronomy before astrology's collapse, as was the study of electricity in the eighteenth century, or that of hypnotism in the middle of the nineteenth. What is more, the average man demands that phenomena of this order shall be included in his scheme of things. Science cannot yet do this for him; and accordingly the dwelling-place that we are building must still be incomplete; it is for those who come after to build the upper stories.

This cannot be helped. What we build, we must build firmly; on what is yet to be built, science cannot pronounce, except to say that she knows that it will be congruous with what has gone before.

What general principles, then, do we assume? We assume that the universe is composed throughout of the same matter, whose essential unity, in spite of the diversity of its so-called elements, the recent researches of physicists are revealing to us; we assume that matter behaves in the same way wherever it is found, showing the same mode of sequence of change, of cause and

effect. We assume that there has been an evolution of the forms assumed by matter; that, in this solar system of ours, for instance, matter was once all in electronic form, that it attained later to the atomic and the molecular; that later, colloidal organic matter of a special type made its appearance, and later still, living matter arose. That the forms of life, simple at first, attained progressively to greater complexity; that mind, negligible in the lower forms, became of greater and greater importance, until it reached its present level in man.

Unity, uniformity, and development are the three great principles that emerge. We know of no instance where the properties of matter change, though many where a new state of matter develops. The full properties of a molecular compound such as water, for instance, cannot be deduced at present from what we know about the properties of its constituent atoms of hydrogen and oxygen. The properties of the human mind cannot be deduced from our present knowledge of the minds of animals. New combinations and properties thus arise in time. Bergson miscalls such evolution 'creative'. We had better, with Lloyd Morgan, call it 'emergent'.

With mind, we find a gradual evolution from a state in which it is impossible to distinguish mental response from physiological reaction, up to the intensity and complexity of our own emotions and intellect. Since all material developments in evolution can be traced back step by step and shown to be specializations of one or more of the primitive properties of living matter, it is not only an economy of hypothesis, but also, in the absence of any evidence to the contrary, the proper conclusion, that mental properties also are to be traced back to the simplest and most original forms of life. What exact significance is to be attached to the term 'mental properties' in such organisms, it is hard to say;

we mean, however, that something of the same general nature as mind in ourselves is inherent in all life, something standing in the same relation to living matter in general as do our minds to the particular living matter of our brains.

But there can be no reasonable doubt that living matter, in due process of time, originated from non-living; and if that be so, we must push our conclusion farther, and believe that not only living matter, but all matter, is associated with something of the same general description as mind in higher animals. We come, that is, to a monistic conclusion, in that we believe that there is only one fundamental substance, and that this possesses not only material properties, but also properties for which the word *mental* is the nearest approach. We want a new word to denote this *X*, this world-stuff; *matter* will not do, for that is a word which the physicists and chemists have moulded to suit themselves, and since they have not yet learned to detect or measure mental phenomena, they restrict the word 'material' to mean 'non-mental', and 'matter' to mean that which has material properties.

You will remember William of Occam's razor: 'Entia non multiplicanda praeter necessitatem;' when we are monists in the sense I have just outlined, we are using that weapon to shave away a very unrestrained growth of hair which has long obscured the features of reality.

Holding to these principles, we must, until evidence to the contrary is produced, reject any explanation which proceeds by cataclysms, or by miracles; a miracle becomes (when not an illusion) simply an event which is on the one hand uncommon, and for which, on the other, there has been found no explanation. Revelation too goes by the board—save a revelation which is simply a name for the progressive increase of knowledge and insight.

Last, but not least, we do not pretend to know the Absolute. We know phenomena, and our systems, in so far as scientific, are interpretations of phenomena.

. . . .

Religion has been defined in a hundred different ways. It has been defined intellectually—as a creed; as myth; as a view of the universe. It has been defined emotionally—as consisting in awe; in fear; in love; in mystical exaltation or communion. It has been defined from the standpoint of action—as worship; as ritual; as sacrifice; as morality. Matthew Arnold called it 'morality tinged with emotion'; Salomon Reinach 'a sum of scruples impeding the free use of human faculties'. Jevons makes the experiencing of God the central feature; and so on and so forth. Is it possible to find any common measure for all these statements? Would it not be better to unite with those who cut the Gordian knot by writing down all religion simply as illusion? No. For their point of view is meaningless. Even illusions are, in themselves, facts to be investigated; and even illusions have a basis.

But it is not necessary to believe that it is an illusion; the knot may be untied. Ritual, Creed, Morality, Mystical Experience—all these are manifestations of religion, but not religion itself. Religion itself is the reaction between man as a personality on the one side, and on the other, all of the universe with which he comes in contact. It is not only ritual, for you may have obviously non-religious ritual, as in a court ceremonial, or a legal function: it is not merely morality, for men may practise morality, the most austere or the most *terre à terre*, uninspired by anything that could remotely be called religious: it is not belief, for we may have beliefs of all kinds, even to the most complex scientific beliefs concerning the universe, which have yet no connexion with

religion: it is neither communion in itself, nor ecstasy in itself, as many lovers and poets could tell you.

But because it is a reaction of the whole personality, it must involve intellectual *and* practical *and* emotional processes: and because man has the powers of abstraction and association, or rather because his mind in most cases cannot help making associations and abstractions, it follows that it will inevitably concern itself, consciously or sub-consciously, with all the phenomena that it encounters, will try to bring them all into its scheme, and will try to unify them and frame concepts to deal with them as a whole.

Some men will be more concerned on the emotional, others on the intellectual, others again on the moral side: but it is impossible to separate any one of the three aspects entirely from the others.

We will begin with and treat mainly of the intellectual aspect of the problem, the credal side. For one thing, science has more direct concern with it than with the others; for another, more continuous and startling alterations have had to be made in it; and finally, the actual problem is there felt most acutely at the present moment.

What, then, is the problem? In the terms of our definition of religion, it is in its most general terms as follows: Man has to live his life in a world in which he is confronted with forces and powers other than his own. He is a mere animalcule in comparison with the totality of these forces, his life a second in comparison with their centuries. By his mental constitution, he of necessity attempts to formulate some intelligible account of the constitution of the world and its relation to himself—or should we rather say in so far as it is in relation to himself?—and so we have a myth, a doctrine, or a creed.

At the present moment, as we have already seen, there

appears to be an irreconcilable conflict between orthodox Christianity and orthodox Natural Science. The one asserts the existence of an omnipotent, omniscient, personal God—creator, ruler, and refuge. The other, by reducing ever more and more of natural phenomena to what we please to call natural laws—in other words, to orderly processes proceeding inevitably from the known constitution and properties of matter—has robbed such a God of ever more and more of his realm and possible power; until finally, with the rise of evolutionary biology and psychology, there seems to be no place any more for a God in the universe.

Stated thus, the opposition is complete. But let us return on our footsteps, and trace for one thing some of the history of religious beliefs, for another reinvestigate, from a slightly unusual standpoint, the actual knowledge of the Universe which science has given us.

Man has developed: in early stages, his physical and mental capacities developed; in later stages development has been mainly restricted to his traditions, ideas, and achievements. As part of his development, his religious ideas have altered too.

At the beginning, he appears to have no ideas of a God of Gods at all—merely of influences and powers, obviously (he would say) inherent in the forces of Nature, magically inherent in certain objects and actions—fetishes and incantations. He seems scarcely to have been conscious of himself as an individual, or of the full distinction between self and the external world.

Later, perhaps as the idea of his own personality grew, he began to ascribe a more personal existence to the forces with which he came into contact, and so to turn them more and more into beings that can properly be called Gods: polydaemonism arose and in its turn gave place to polytheism.

But while rigid custom was at first the only morality, and each external power and each human activity was regarded separately, later the rise of civilization led to a modification of custom, to a reference of action and belief to the standards of pure reason, and to an attempt at unification. Once this occurred, and equally so whether the attempt at unification had an intellectual or a moral basis, polytheism was doomed. Its downfall has been often described; the reasons for it are suggestively put by Jevons in his little book, *The Idea of God*. It passes through a stage where one among the gods is pre-eminent: but finally even that does not suffice, and in its place arises a monotheistic creed.

Monotheism may start as a purely local or tribal affair—my one God against yours. But this idea, too, is self-contradictory, and merges into that of one God for all men. The primitive anthropomorphism which had invested the first vague and mysterious spirits with human parts and passions, human speech and thought, also fell into gradual desuetude. It was kept up as a symbol, or because of the difficulty of describing a God except in terms of human individuality, but its literal truth was deliberately denied. God became different from and more than man—omnipotent, omniscient, with no parts, with no limitations: but he retained personality—in other words, a mental or spiritual organization of the same general kind as man's, however superior in degree. With time, the divine personality became compounded more and more of man's ideals instead of his everyday thoughts and attributes. And thus and that God remains. He has created everything; he is in some sense immanent in the world, in some sense apart from it as its ruler—you take your choice according to your philosophic preferences. Beyond that, organized religious thought has not gone; and now it finds itself fronting science in an impasse.

That, very briefly and roughly, is how man's idea of God has developed. But how have man's knowledge and ideas of the natural universe developed? What has Science to say to the impasse?

Man has to deal with three great categories of phenomena—the inorganic, the organic, and the psychic. In the inorganic, chemistry first and then physics have given us a picture whose broad outlines are now familiar. There is but one type and store of energy in Nature, whether it drives a train, animates a man, radiates in heat or light, inheres in a falling stone. There is but one substance. All bodies of trees, of men, of rivers and rocks, the clouds in the air and the air itself, precious stones and common clay—all can be resolved into a limited number of elements. And these elements in their turn can be resolved into combinations, differing, it appears, only quantitatively from each other, of electrical charges; so that at the last all matter is one, and becomes perhaps indistinguishable, or at least inseparable, from energy. There is no personal operator for particular happenings; the lightning and the volcano are the inevitable outcome of the material constitution of things, equally with the form and colour of a pebble and with the fact that it will drop to the ground if it is let fall. All is impersonal order and unity.

There is, however, one other great fact about the system of inorganic matter. The energy contained in it tends to be degraded, as the physicists say—in other words to become less readily available. There is available energy in moving matter. There is potential energy in all matter, dependent upon whether it can be set in motion. But if the sea were to cover the whole surface of the globe, it would be impossible to extract energy from running water as we do now, because no water would be running. So too heat is energy; but it is only available when it can flow, when there are hotter and

colder bodies. The law under which transformations of energy operate has now been investigated, and it has been established that in every energy-transaction a certain modicum goes to waste as unavailable heat, so that, unless some at present unforeseen change occurs, the last state of the universe, considered as a purely physico-chemical mechanism, will be one of death, of inactivity, with all matter at a uniform low temperature and the whole stock of energy locked up and unavailable in this sea of tranquillity. True for one thing that an almost inconceivable number of millions of years must elapse before this 'death of matter' is realized; and for another that we are unable to understand how such a progressive degradation could have been in operation from all eternity. We must not expect complete knowledge within a few years or a few centuries; but even if the beginning is veiled—for there is no more evidence for a 'creation' than for (say) a rhythmic reversal of the direction of energy-availability—and if it is always possible that some unforeseen change in the process should occur before the whole runs down, yet it is a fact (and we are resolved to be agnostic save about facts) that, here and now, a direction is to be observed in the evolution of inorganic matter, by which natural operations are tending to become less active, and the amount of available energy is diminishing. If it continues indefinitely, first life, and later on all activity and change whatsoever will cease. There is a tendency towards death and towards unchanging inactivity.

The next great category is that of the organic, of living matter. We have to consider its origin and later history. So far as constitution goes, living matter is merely a special and highly complicated form of ordinary matter; and there can be no reasonable doubt that it has originated naturally from non-living matter.

While the *main* direction of the inorganic has been towards degradation of energy, it has shown another subsidiary direction towards the production of more and more complex forms of matter. If our general ideas are correct, there must have been a time when matter in our ordinary sense of the word did not exist—there can have been no atoms, only free electrons. From this state, there evolved one in which the various electron-systems that we call atoms first appeared; later still, atoms could join with atoms to produce molecules. Leaping over vast periods, we would come to the time when radiation had brought the temperature of the earth surface below 100° C.; water then could form from steam and solution occur. Through solution, all soluble elements, which would otherwise remain locked in the inactivity of the solid state, are enabled to enter upon a new phase of mobility, of chemical life, as we may say. Only in water could colloid carbon compounds first be built up, and only from such substances could life originate.

Living substance, or at least much of it, must be formed of molecules containing thousands of atoms, each atom in its turn a system of circling electrons. Here already is a vast increase of complexity: it remains to be seen whether the same tendency is perpetuated later.

The evolutionary concept is to biology what the doctrine of the conservation of energy has been in the physico-chemical sciences—an indispensable preliminary to proper methods of attack. But while great stress has been laid on the various *methods* by which evolution may be supposed to have taken place—Natural selection, Lamarckism, orthogenesis and the rest—biology has concerned herself comparatively little with the *form* of the process in itself. But it is here that evolution becomes of value to us in our present search; for once more we become aware of a direction. Partly from the direct

evidence of palaeontology, partly from indirect evidence, but along many converging lines, we can form an idea of this direction which in broad outlines is unassailable.

During life's existence on earth—a period to be reckoned in hundreds and probably in thousands of millions of years—there has been an increase in various of its attributes. But just as in the inorganic world electrons and atoms still exist as such side by side with molecules, so also the earlier types of living matter continue to exist side by side with the later. The increase is not therefore seen uniformly in all forms at once, but is most easily observed by studying the *maximum* level attained. Size, for instance, is one of these attributes; and whereas to-day all variations are to be found between ultra-microscopic disease germs and vast organisms like whales and elephants, there has been a gradual steady increase (tending to a limit) in the size of the *largest* organisms existing at any one period.

If we confine ourselves for the moment to the material side, we find that the directional change in organic evolution can be reduced to this—to an increase of the control exercised by living matter over the environment, and of its independence of the environment—two reciprocal aspects of a single process. When we look more closely into the means by which this has been achieved, we shall see an increase of the maximum not only in size, but in complexity, in length of life, in efficiency of particular organs, in co-ordination of parts and general harmony, in improvement of sense-organs, and, continuing even after other tendencies have reached their limits, in brain-size and consequently in complexity of mode of reaction and behaviour.

If we turn to the psychological side, we find that there has been an increase in the intensity of mental process. This is apparent in all aspects of mind, on that of emotion

equally with that of knowledge, of volition equally with that of emotion. To be an amoeba or a worm is to live a life almost without windows. Perfection of sense-organs makes it possible for life to be aware of the different types of outer events, whilst memory and, later, associative memory give the possibility of understanding their history. In higher forms volition can be maintained for longer and longer intervals, can attain greater intensity, and can fix itself upon ever more and more distant objects. With depth of feeling comes also differentiation, so that finally we find in ourselves the possibility of organizing various blends of the simple emotions into the compound emotional forms such as reverence and admiration, called *sentiments* by McDougall.

Biologically speaking, therefore, the direction observable in mental evolution is again towards increased control and increased independence; by mental and cerebral improvement there is introduced a greater accuracy and a greater range of control, as well as better adjustment between organisms and environment, than would be otherwise possible to the same bodily organs.

The direction of life may therefore be roughly summed up in the two words 'more life'—more both in quantity (have not both land and air been colonized during evolution?) and also in quality. More matter has been stolen from the lifeless and embodied in the living; and the living begins to be less helpless in face of the lifeless.

The direction of living matter is thus in many ways opposed to the direction to be seen in inorganic matter; yet not only has the organic arisen from the inorganic, but its direction continues one direction already traceable before the appearance of life.

Finally, we come to the psychological aspect of the universe. We have already touched on it in connexion with biology, and found that in many ways at least the

development of mind follows the same lines as that of living matter, and helps forward the general trend of life.

But finally a kink occurs, a critical point, similar to that seen at the origin of living from non-living matter. There the attributes of living matter which mark it off from inorganic matter become dominant—its capacity for self-reproduction, its tendency to organization. The colloid carbon compound had been the highest known independent unit; from now on, this place was taken by the organism.

In exactly the same way, in the final stages of evolution (as witnessed abundantly by fossil mammals) complexity of purely bodily organization had reached a limit, and survival, as is evidenced by increasing size of brain, came to be determined more and more by mental qualities. Finally the curve of mental development caught up with that of body, and intersected it: mind became the dominant factor in the new type of organism, and in the subsequent history of the evolutionary process. The *organism* ceased to be the highest unit, and gave place to the *person*, or self-conscious individual with organized mind.

This new critical point was reached when man arose; many authors recognize it for what it is, the beginning of a new era, by christening the subsequent geological period the Psychozoic. That period, geologically speaking, has yet run but a tiny span; and we are no more entitled to think that we have reached or even imagined the possibilities of its future evolution than we should have been entitled to regard the possibilities of purely biological evolution as having been exhausted after the far longer period needed to give rise to a coral polyp or jelly-fish as highest existing types of organism. Even man as a biological species is in his infancy, not to speak of other psychozoic types that may be waiting in the womb of time.

But what are the characteristics of this new phase? In the first place, mind has become self-conscious; thus the evolutionary methods of psychozoic organisms may become conscious, and they come to direct their own evolution instead of having their destinies shaped by the blind forces of natural selection.

In most respects the same direction as before is pursued, but new methods are introduced. The rate of change, of movement in that direction, is accelerated; and the possibility is given of eliminating a vast deal of waste. A watchmaker sends out very few defective watches: why? because he makes his watches on a preconceived plan. Even when an improvement in watch construction is introduced, he can draw up his plan beforehand, and at the worst, waste only time and paper, instead of metal and far more time. Ideas do not need to be embodied before selection can act upon them; thus an increasing amount of evolutionary change will take place through the natural selection of ideas than through the older and far more wasteful process, natural selection of individuals and species.

Finally, values appear upon the scene. If we could ask a wild animal such as a fox what gave value to its life, and it could answer us, it would doubtless say food, sleep, comfort, hunting, sexual pleasure, and family companionship. But it cannot answer; nor can it know the value of what it pursues, but only appreciate the result. Strictly speaking, values do not exist for it. However, even if we allow ourselves to speak of values in the life of pre-human organisms, we see immediately that wholly new values are introduced after the critical point.

Putting it summarily, we can say that, with the rise of mind to dominance, various activities of mind come to be pursued for their own sake, to have value in them-

selves. Our life is worth living not only for the sake of eating and drinking, sleeping, athletics, and sexual pleasure. There is a value attached to knowledge for its own sake, apart from the possible access of control that it may bring. But this is new, a property of man alone; not even Athena's owl will exert itself through laborious years to understand celestial mechanics or physiology. The highest anthropoids do not attempt to create works of art, which for man come to have value in themselves. Natural beauty comes to have its value too; a cow (so far as known!) does not interrupt the business of its life to admire the sunset, whereas men may and do. Behaviour also is implicated: with the entry upon the scene of that practically unlimited number of possible reactions which give us what we call free will and choice, there comes a conviction that some modes of action are higher than others; and so a scale of moral values comes into being.

Nor is it merely that values, in the strict sense, are created; nor that new values come into being. But with the enlargement of mind and its more perfect organization, there arises a new method of appraising values, and so a new type of value altogether. I mean, of course, the so-called *absolute values.* Absolute values are never absolute in the sense of absolute completeness; they are relative to two things—to external reality and to our mental powers and organization.[1] They are abstractions; we generalize the value in our minds, and at the same time raise it to the highest pitch of intensity

[1] A confusion of thought easily arises here. It may be absolutely true that 2 and 2 make 4; we may be absolutely right in certain cases to tell a lie; or may find an expression of absolute beauty in some one lovely thing. But we may grow to find that same thing aesthetically unsatisfying; we can imagine a state of society in which it would never be right to lie; while our correct knowledge of elementary arithmetic is something very partial and incomplete.

we can. An interesting point arises from this way of thinking. Apart from the guarantee of our own convictions, the observable direction of living nature is our guarantee of right: or one had better say that it is at once the guarantee and the touchstone of our convictions. But two things may be moving in the same direction, and, if one be moving much slower than the other, the slower may impede the faster; a pedestrian procession making eastward along Fleet Street will hold up the life of the City for a time, and cows walking along railways are treated as obstacles by trains proceeding in the same direction. So it comes about that much that was once progressive in organic evolution has become an obstacle or a drag to psychozoic evolution; it is *relatively* retrogressive, and, from our present standpoint, bad. To take the simplest and most fundamental example: evolution by blind natural selection was the method of progress for organisms below man. Unceasing struggle and courage was the chief factor in producing the grandeur and strength of the lion, the swiftness and grace of deer, the brilliance and lightness of the birds. But if the same end can be obtained both more quickly and more bloodlessly by new methods, then the old stands condemned. Here lies the key to the problem propounded by Huxley in his Romanes Lecture—the problem of man's relation to the rest of the cosmic process, at once sprung from it by gradual generation and separated from it by an absolute and unbridgeable chasm, at once one with it and in deadly combat with it and all its ways.

Our mode of envisaging the problem illuminates it, and shows it as inevitable and intelligible instead of insoluble and tormenting; and illuminates, too, many other minor problems of good and evil. But all this is a side-issue: *revenons à nos moutons.*

Unknown, or neutral, or hostile power: a movement

similar in direction to the direction in which history on the whole shows we are moving, and to that which we desire with our highest aspirations, but operating blindly; an acceleration of that movement by the coming of mind to biological predominance, with certain consequent minor changes in direction but major changes in speed and in methods. Three tendencies, but all founded in one unity, and each arising out of the other—that is the picture drawn for us by the present state of science. In this sense, and in this only, can it be said that 'all things work together for righteousness'.

One word on an important side-issue—the problem of evil in man, of stagnancy and degeneration in organic evolution. Degeneration often does occur—a reversal, in other words, of the main tendency. But the positive fact remains that the *maximum* level is progressively raised, and that we find that stagnation of development or even sometimes degeneration have been factors indirectly helping on the main direction.

We must accept the positive main direction for what it is—an external sanction for faith; confess that we do not understand the detailed working of the whole, but see in the change of methods brought about by the rise of mind a hope that we shall gradually learn at least to dispense with much waste and evil and degeneration in the further course of evolution.

This main direction gives us cause for optimism. The exceptions to it temper that optimism. But the direction is there.

As we shall see later, we may either call the sum of the forces acting in the cosmos the manifestations of God, who in this case must be the Absolute God, and unknowable except through these manifestations. Or we may confine the term God to its anthropological usage, as denoting the objects of human religion, in which case

we must admit that the term God as understood by man is constituted by man's idea of the forces acting in the cosmos, so that not only are these forces involved, not only a possible Absolute God behind them, but also the organizing power of human mind.

I wish you here to agree to my adopting the second alternative and giving the name of God to the sum of the forces acting in the cosmos as perceived and grasped by human mind. We can therefore now say that God is one, but that though one, has several aspects. There is one aspect of God which is neutral to us, in a way hostile, mere Power operating in the vastness of the stellar universes, apprehended only as orderly, tending in a direction which appears to be in the long run inimical. It is to this aspect of God that Mr. Wells has given the name of the Veiled Being—a somewhat primitive term for a true idea. There is another aspect, which is the one seen operating in that sphere which comprises the whole of life upon this earth—a sphere infinitesimal in relation to the whole, yet still vast in relation to ourselves. This aspect of God is our refuge and guarantee, for here we find our assurance that our human life is a part of a whole that is not antagonistic, but moves in the same general direction as do our history and our aims. There does exist, in Matthew Arnold's words, 'a power, not ourselves, that makes for righteousness'. And this second aspect is not wholly separate from the first, in spite of its difference of direction; for the first is its parent, physically and temporally, and the direction of biological progress is the continuation of a line of development marked out, within the opposed inorganic direction, even from the first.

Next, there is a more immediate and more often-demanded assurance that we, as individuals or as single communities in space or time, are at one with humanity

as a whole. Here it is that we look to the third aspect of God, which enshrines the directive forces operating in man. These directive forces are our instincts, our needs, our values, our ideals. When those are harmonized with each other and with the outer world by reason and experience, they form a power which we can see has been directive, normative in the past, and will continue to be so in the future. It alters with man's development ; but after a first rudimentary phase, its main outlines, its type of organization remain the same, for man's instincts and ideals do not greatly change, and their harmonization with each other and with experience will generally proceed in the same broad way. Although in a sense this aspect is the smallest, as comprising the smallest physical field, yet in another it is the largest, since man's ideals are in themselves unlimited, non-finite; and the values involved, to our present type of mind, appear ultimate. This third aspect of God is again historically the offspring of the second, and through the second of the first.

Matter, life, mind—this is the simplest classification of phenomena. By means of processes analogous to obtaining a resultant by the parallelogram of forces, we can obtain a resultant of material operations in general, vital operations in general, and mental operations in general, numerous and varied in direction though they be. Life is the link between the other two. Living matter is so definitively one with non-living matter, not at all obviously one with mind; yet the direction of living matter is obviously similar to that of the direction of mind, not at all obviously one with that of non-living matter.

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It is a simple fact that the conception which man has of the universe and its relation to himself exercises

important effects upon his life. A name therefore is needed for this anthropological phenomenon. *God* is the usual name applied, and we shall retain it in default of another, premissing that the word, like many similar general terms—'love', or 'life', or 'beauty', say—can be defined and applied in many ways, and that we apply it here in a particular and perhaps somewhat novel sense.

God in this sense is the universe, not as such, but so far as grasped as a whole by a mind, embodied in an idea, and in consequence capable of influencing that mind, and through it the whole course of events. It is not grasped as a mere sum of details, but, however vaguely and imperfectly, as a single idea, unitary in spite of its complexity. Nor is it the universe in itself, but only so far as it has been thus grasped by mind. There exists no other meaning of the term which, on analysis, is found to convey anything, or at least anything scientific or comprehensible to us. We may reason that there is an Absolute God behind the universe and our idea of it. But we have no proof of this statement, and such an absolute God is, as Spencer pointed out, an Unknowable, and accordingly no concern of ours. That part and these aspects of the universe which have been grasped by us may prove to contain the key to many of our difficulties; meanwhile we can only be humble and admit that our idea of God, even in this restricted sense, is still extremely incomplete: and in this sense there is a God far greater than our present idea and knowledge of God, only waiting to be discovered.

That which it is essential to establish is our way of looking at the problem. The universe does come into relation with our minds, and there, owing to the way it and our minds are organized, generates an idea which exerts an influence upon us.

The external basis of the idea of God is thus constituted by the forces operating in the universe. The universe is a unitary whole, greater and more powerful than ourselves, and its operations have resultants in certain main directions—these are phenomena which we constatate like any other phenomena. They, and that other phenomenon of our contact with the Universe and our exposure to the play of its forces, give us our objective knowledge of God. The rest of our idea of God, the inner component, depends upon the mode of action of our minds.

So far then, we have shown that recent advance in science, particularly in our understanding of evolution, has enabled us to give a more objective account than ever before of what is involved in the concept *God,* and so to pave the way for a consensus of thought on the question.

It will be observed that there is no idea of personality implicit in this conception of God—God may or may not possess personality. It will be for us later to investigate that particular aspect of the problem.

It now remains to deal with the inner reality. Man has a wholly new type of mind. He is social and capable of speech. He generalizes, and he has a very highly developed power of association. This combination gives him a great many possibilities hitherto denied to life. In the first place, he is able to order his experiences in a totally new way, differing from the old very much as a classified card-index differs from a rough diary-record of events. The organization of his mind is elastic, capable of indefinite expansion and of specialization in any direction.

That being so, there will be always parts of his mind wholly or at least partially undeveloped; and in any case the capacities which he must employ in his everyday life, the region of his mind illuminated by the attention

needed in the struggle for existence, constitute but a fraction of his mental self and its potentialities.

This brings us on to one of the most important achievements of modern psychology—the discovery and analysis of the subconscious. Impossible here to go into detail; we must content ourselves with a few broad statements. When we speak of the subconscious mind, we mean that in man there exist psychoneural processes (to use the most non-committal term), which appear for many reasons to be of the same nature as those of the normal mind (in that they are associated with the same parts of the nervous system, fulfil the same general biological functions and probably operate through similar mechanisms), with the single exception that we are not conscious of them as such.

The conscious mind, that which we think of as the basis of our mental individuality, as our personal being, is the result of a long process of organization. We come into the world with a set of instinctive and emotional reactions only waiting their proper stimuli to be fired off, with a capacity for learning, for amassing experience, and a capacity for modifying our instincts and our behaviour according to our experience. We incorporate experience in ourselves, and in so doing we alter the original basis of our reactions; a strongly emotional experience colours all that is closely associated with it; and so after birth we are continually making our mental microcosm not only larger but qualitatively more complex, in exactly the same way as before birth our body grew not only in size, but also in complexity of organization.

Parts of experience or of inherited tendencies may fail to become organically connected with the main parts of our minds, simply because attention has never been focussed on them, or has not attempted to bring them into relation with the rest. They are, shall we say, like

bricks which might have been used in a building, but have been left lying on the ground by the workmen.

Still more remarkable are the methods by which harmony is achieved in the personal mind. It is obvious that a conflict of any sort between parts of the mind will waste energy, will prevent a clear-cut reaction being given in either direction, and so constitute a grave biological disadvantage by making us fall between two stools. If a child gets a serious fright in the dark, darkness will tend to arouse fear. But darkness also comes with evening and with the time for sleep. Two modes of reaction to darkness are therefore given, and they are self-contradictory. One part of the mind comes down its pathway towards action, and finds itself met by another which is coming along the same path in the opposite direction. If neither moves, there is a conflict; in our hypothetical case sleep is delayed; and if it comes, is disturbed by nightmares—the echoes of the fright—and the childish organism suffers.

Exactly similar conflicts in which fear plays a part may occur in adult life, e.g. in so-called 'shell-shock'; or the sex-instinct may come into conflict with other parts of the personality.

These conflicts are resolved through one tendency or part of experience being passed into the sub-conscious, where it no longer can meet its opponent on the path to action. And this passage into the subconscious can be apparently automatic, unwitting, when it is called *suppression*, or performed only by voluntary effort, when it is called *repression*. In the former case, it would appear that the conflict may wholly or almost wholly cease; whereas in the second, the repressed portion of mind is perpetually searching to come to the surface again, and must thus perpetually be held down by force.

If we hold by our metaphor of the building, then in

suppression, bricks which would not go well with the rest are stacked quietly in the cellars; while in repression, part of the workmen want to build a different sort of building, and have to be forcibly held down by some of the rest to prevent their doing so.

But in whatever way the subconscious may be organized, it is always with us, and there will always be a remainder of our soul, or of its possibilities, which is not incorporated in our personal life at all, as well as much which is not closely organized with the main everyday personality, but is connected with it only by vague and loose bonds, approachable only by narrow pathways instead of by broad roads.

There is another process at work in the human mind which is of the utmost importance for our problem. I mean the process of sublimation. If it is not easy to give a short and clear definition of sublimation, at least the process is familiar to all. The commonest example is 'falling in love', where the simple sex-instinct becomes intertwined with other instincts and with past emotional experience, and projects itself in wholly new guise upon its object. We may perhaps best say that a sublimated instinct has more and higher values attached to its satisfaction than one unsublimated. The mere satisfaction of the sexual impulse need be little more than a physiological desirability; but the satisfaction of passionate love involves every fibre of the mental organism, hopes and ideals converging with memories and instincts on to the highest pitch of being.

In such a case sublimation occurs with the normal object of the instinct. But the elasticity of man's mind permits of further complication: the instinct may be not only sublimated but attached to new objects. Through the cogs and spirals of the mind, the sexual instinct may find an outlet at higher levels, and contribute to the

driving force of adventurous living, of art, or as we may see in many mystics—St. Teresa for example—of religious ecstasy.

It is as if a swift stream were falling into underground channels below the mill of our being, where it could churn and roar away to waste. But some of it is led off at a higher level, and we can learn to lead off still more; and we can make an installation of pipes whereby it can be taken up to the original level, and made to fall through new machines and do any work we may ask of it.

The mechanism of sublimation, however, deserves a few more words. Recent work in biology has shown that in low forms of animals and in early stages of high forms, the head-region is in a certain sense dominant to the rest, in that it forms first and independently; but that, once present, it exerts a formative influence upon the rest of the body, keeping the various organs in some way under control, making them different from what they would otherwise have been, and so moulding them to the part of a single and higher whole.

An extremely similar process is at work in sublimation Ideas and ideals can be naturally dominant over others, or they can become dominant through becoming associated with primarily dominant ideas, or by receiving a larger share of attention. Attention, concentration, what you will, is one of the most remarkable mental functions. Not only can the metaphor of intense illumination of a particular field be justly used of it, but we may say that it seems to accelerate the flow of mental process through a particular channel, and so to draw into that channel the contents of other channels in connexion with it, just as a rapid flow of water through a pipe sucks in water from connected pipes.

As a result of this, sublimation involves not the suppression or repression of instincts and emotional

experiences, nor merely the summation of them with another instinct, but their utilization as parts of a new whole, of which the dominant instinct is like the controlling head.

When the sex-instinct is repressed, the emotional and religious life is meagre, though often violent. When the sex-instinct and the religious feeling exist side by side, without conflict but without union, you have 'the natural man' of St. Paul; but when the religious ideals are dominant, and can catch up the sex-instinct into themselves, and in so doing give it a new form and a new direction, then you get one of the highest types of emotional lives. Or fear may be sublimated to reverence; or sex again to art or to philanthropy.

In every case, a new and more complicated mental activity or organ is arrived at; and the same process that we saw at work in biological evolution—the creation of ever more complex units—is thereby continued.

Then we come to the fact that man displays disharmonies of mental construction, together with an innate hankering after harmony. His most obvious disharmony is that between the instincts that are self-regarding and those that are other-regarding—between man's egotistic and his social tendencies.

It appears that man became gregarious quite late in evolutionary history. Through natural selection, sufficient 'herd-instinct' was developed to insure that men would on the whole stand by the tribe in danger, that the tribe should become a real biological unit. But it was impossible wholly to harmonize these new social instincts even in the simplest societies, with the old, deeper-rooted, individualist tendencies; and as life became more complex and choice wider, conflict grew more and more frequent.

Another obvious disharmony in modern civilized com-

munities is the fact that sexual maturity occurs long before marriage is possible or desirable.

In all this, there is inevitably a field for all the various combinations of suppression, or repression, or sublimation.

Man's gregariousness, together with his power of speech, learning, and generalization, have led to the development of a new thing in the world—persistent and cumulative tradition. I use tradition in the broadest sense, as denoting all that owes its being to the mind of man, and is handed down, by speech or imitation or in some permanent record, from generation to generation. Language, general ideas of right and wrong, convention, invention, national feeling—all this and much more, constituting the more important part of the human individual's environment—is part of tradition; and tradition is pre-eminently and inevitably social. However individualistic we may wish to be we cannot escape modelling by this social environment.

The general effect of man's gregarious instinct is that he desires to find himself in harmony with some traditions, with the ideas that modern jargon likes to call the *herd* to which he belongs. The herd ideas, the traditions, may be those of a nation or of a stratum within the nation; of a whole class or of a clique; of science or of art; of a retired monasticism, or of an all-embracing world-civilization. But they are always herd ideas, and through them man is always member of some community, even though that community be tiny, or consist mainly of writers dead and gone; and he always strives to put himself in harmony with the traditions of that community.

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A long-winded introduction enough; now for the bearing of it. One of the essentials of every religion is its treatment of the subconscious, is its view and its practice as regards the relation between the personally-organized

part of the mind to the remaining non-personal reservoirs. At first the non-personal part is regarded as being wholly outside the organism, and its occasional flooding up into the narrower ego is regarded as an operation of an external personality, a spirit, a God Comparatively late, it is recognized as part of the organism, but the process by which connexion is made is still regarded as divine, and called inspiration. Such ideas belong to the adolescence of the race, in precisely the same way as the discovery and acquisition of great tracts of this subconscious territory will always necessarily constitute part of the adolescence of the individual. But any developed religion must always in some way help to make these great reserves of power accessible, always teach the enlargements of the personal ego which their conquest brings about. This is one of the ways in which, to use current religious phraseology, self may be lost, and found again on a different plane.

Religion must further always provide some internal harmony, in counterpart to the harmony demanded in the unitary comprehension of external reality. The various activities and experiences of life, as they are originally given by heredity to the child, are either independent, or else antagonistic and disharmonious. There must be some means provided for bringing all of them into a true organization—in other words into a whole which, though yet single, is composed of co-operating parts. Here again the actual responses of actual religions have been many and various; but they all operate by suppression, repression, and sublimation, or by a combination of these.

It can at once be said that sublimation is the right and highest way, and that two of the criteria of religious progress are to be found in the stress laid upon sublimation, and in the enlargement and the elevation of the

dominant ideas at work in the sublimating process. It is the right and highest way because through it no spiritual energy is wasted, and the age-long path of progress towards ever higher levels of complexity in organization is still continued. Among religious teachers, both Jesus and Paul laid great stress on this—on the freedom, the emancipation from the shackles of an external law made possible by the apprehension of some highest harmonizing principle and the subordination of all other ideas and desires to it. Once one can see and learn to follow such a principle, whatever one does is in a sense right, because one's desires are all subordinate to a desire for right, and to something which is right. Perhaps it would be better to say that they appear right to oneself, that the haunting, terrible sense of sin is laid to rest, and one's life liberated into free activity, one's energy made all available for achievement.

The sense of sin, if not universal at one or other period of life, is almost so, and comes from an apprehension of inner disharmony. As one would expect, selfishness and sex are its most common roots; and whenever it exists, then the necessary preliminary to any further progress of one's being is that it should be made to disappear. It can disappear, as in St. Paul's natural man, by a suppression of part of the mind or of the connexion between parts, or by a failure to make certain connexions, or it can be eradicated by a growth of callousness; or—and I take it that this is the proper religious solution—by discovering a clue which will harmonize the two apparently opposed sections of experience, the two antagonistic tendencies, and so resolve the problem with no loss of energy or of vital possibilities.

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Finally, there remains to be considered the mode in which the mind may best organize the ideas of external

reality given to it by its pure cognitive and intellectual faculties.

Even from the purely scientific point of view, generalization is obviously of value. When we have found unity in the outer world's apparent diversity, direction in its apparent disorderliness, we have obviously achieved a great gain. But religion appears to demand something more. If for a moment we look at the matter pragmatically, we shall find that a number of the great mystics (and a large majority of those of our own occidental type and tradition) speak of their experiences of 'divine communion' as being communion with a *person*.

What does this mean? We have seen that a purely intellectual analysis gives us no handle for finding personality in God. Can we suppose that this direct intuition gives us that handle? To say so, to my mind, would be simple obscurantism. Intuition, if it shows us reality, can only show a reality capable in the long run of intellectual analysis; to deny this is to deny all our premisses. No: their intuition shows us that something akin to personality is perceived, but permits no pronouncement as to whether its resemblance to personality is given in its real nature, or introduced into it by their thought.

If we look into the history of religion, we find over and over again that man has taken something from his own mind and projected it into the external world. The magic power of fetishes, the tabus incurred by contact with certain objects, the endowment of the idea of external powers, of God, with human form, the ascription of miraculous influence to places or things—in every case there has been this projection. And there is no reason to doubt that here again there has been a similar occurrence; that man has organized his idea of external power after the pattern of a personality, and has then ascribed this type of organization to the external power itself.

The rival schools of psychology may disagree: but all are agreed that some modes of thinking are more primitive than others, and even in the most educated amongst us tend to persist, often in the subconscious, side by side with more developed methods that have arisen later.

The use of concrete symbols or images is the most widespread of these primitive modes of thought. It is natural and inevitable that the more complex should at the first be described in terms of the less complex, that those experiences for which no proper terminology has been hammered out should be given names out of man's existing vocabulary. That is inevitable: but there is an even more fundamental process at work. It seems as if the human mind works, on its most primitive levels, by means of image-formation, and that emotions and concepts for which no simple image exist may call up symbolic images by association and indeed often dress themselves in these new clothes before they present themselves to consciousness. Some such process appears to take place in dreams (including day-dreams!) and possibly in the ordinary thought-processes of savages. More advanced modes of thought substitute the currency of an arbitrary token such as a word or a formula for the barter of images and concrete symbols; the freshness and vividness of the image is lost, but more efficient and speedier working is attained. However, in most of us the concrete image-using mode of thought is a relief from the apparently less natural and more artificial (though more efficient) operations of reason, and we relapse into it, wholly or partially, more often than we realize.

This unconscious irrational tendency to symbolism, together with the other tendency to project ideas properly attaching to the subjective world into external objects and processes—these between them account for much of the modes of expression so far found for religious belief;

and, since the majority of human beings have a profound distaste for sustained or difficult thought, it is likely that they will continue to account for much in the future.

These are facts of extreme importance. The professional sceptic is at once tempted to exclaim that every such projection and illogical symbolism is illusion through and through, and must be wholly swept aside. He would be wrong. We each of us must know from our own experience the 'influence' (to use a general term) which may inhere in certain things and places. True that the influence is of our own mind's making; but it is none the less real, not only as a momentary existence, but, as the term implies, as exerting a definite and often a great effect upon our lives. The lover who cherishes a ring or a lock of hair; the man who is drawn back to the haunts of his childhood or his youth; the mind refreshing itself with some loved poem or picture;—what do we have in these and innumerable other instances but a peculiarity of mind whereby it may take external objects into itself and invest them with its own emotions and ideas, in such a way that those same objects may later reflect their stored-up emotion back again into the mind? It operates by a form of association; but the actual working resembles the charging of a battery, which may subsequently discharge back. We have in it, in fact, a special faculty which, if rightly used, is of the greatest practical value. Further, the symbol, if rightly used and rightly limited, is of service to most minds in giving a more or less concrete cage for the winged, elusive, and hardly retained creatures of abstract thought.

So too, the organization of the idea of God into a form resembling a personality appears definitely to have, at least with the majority of people belonging to what we call 'Western civilization', a real value.

Biologically, the essence of real personality is first that

it is organized, and secondly that on each of its many faces it can, if I may put it metaphorically, enter into action at a single point, but with its whole content of energy available behind the point. In other words, man as a personality can concentrate his mind on one particular problem of one special aspect of reality; but he is able, if need be, to summon up ever fresh reinforcements if he cannot carry the position—more facts, other ways of thinking and feeling, memories, reserves of will. In a properly organized personality, it is possible to bring the whole to bear upon any single object.

Now when the idea which man makes for himself of outer reality is organized after the same general pattern as a personality, it too will be able to act in this same sort of way.

When man in perplexity interrogates the idea he has of external reality, he is anxious to put his little individual self in harmonious relation with the whole of reality that he knows. Therefore he should organize that reality as a whole, and in such a way that it can all be brought to bear through any single point. The relation between the self and the idea of outer reality is, for any one problem, that of two pyramids touching by their points only; but the points of contact can shift as by miracle over their surfaces as the problem is changed.

But another power of personalities is their power of interpenetration. The purely material cannot do this. One portion of matter cannot occupy the same space as a second portion. It is another of the great differences between the psychozoic and all previous stages of evolution, between man and all else that we know in the universe, that the discrete units reached at this level of organization, the individual human beings, can achieve interpenetration by means of their minds. When you expound a new idea to me, and I grasp it, our minds have

obviously interpenetrated. This is a simple case; but there may be an intimate union of mind with mind which is the basis of the highest spiritual achievement and the greatest happiness. If mind and matter are two properties of the same world-substance, then the rise of mind to dominance has enabled this basic substance to escape from some of the imprisoning limitations which confined it at lower levels of its development: do we not all know that despair at being boxed up, that craving for communion? Using our previous line of argument, we see that the interpenetration of personalities is right, implies a further step in progress, must be part of the basis on which future advance in evolution is to build.

But to apply this to our present point. By organizing our knowledge of outer reality after the pattern of a personality, we make it possible for it to interpenetrate our private personality. If, therefore, we have, in any true sense of the word, 'found religion', it means that we shall so have organized our minds that, for flashes at least, we attain to a sense of interpenetration with the reality around us—that reality which includes not only the celestial bodies, or the rocks and waters, not only evolving life, but also other human beings, also ideas, also ideals.

This, to my mind, is what actually happens when men speak of communion with God. It is a setting, an organizing of our experiences of the universe in relation with the driving forces of our soul or mental being, so that the two are united and harmonized. There is a resolution of conflicts, an attainment of a profound serenity, a conviction that the experience is of the utmost value and importance.

Up till now, we have been defining and analysing: here we see religion in operation. It is a relation of the personality as a unit to external reality as a unit—and a relation of harmony. First, the inner structure of the

mind must be organized into a harmonious unit, then our knowledge of outer reality organized similarly, and finally, in religious experience, the two must be harmonized in interpenetrating union.

Once this harmony has been achieved, it is for one thing so precious in itself that it will be sought for again; the knowledge that we have once reached the stage at which difficulties and doubts are resolved in what the philosophers would perhaps call a higher unity, but which I should prefer to call an organic harmony, is always there to fall back upon in times of discouragement; and finally the harmony is actually woven into the tissue of our mind, just as the amazing physical harmony revealed by physiology has, in the course of evolution, been woven into the structure and working of living bodies; and it can remain there as the dominant idea to which the rest of our ideas, and consequently our actions, are brought into subordinate relation. In other words, it becomes the dominant sublimating principle. Once more, however, the subordination is not forced, but free—we find that what we once thought obstacles are aids, what once seemed sin is now the willing and efficient handmaid of good. That is the fundamental fact in all genuine and valuable religious experience as such—the resolution of conflict and the losing, or enlarging as you will, of the private personality, the mere 'self'. You will find this set out more fully, though in different terminology, in Miss Underhill's books on Mysticism, or in William James's *Varieties of Religious Experience*, or in Thouless's *Psychology of Religion*.

One side-issue. Such experience, if not absolute in the philosophical sense, is absolute for us. If I may be Irish, its absoluteness is relative to our organization and to reality as we perceive it. We cannot perceive anything fuller, more absolute—until perhaps one day, with the

growth of our minds, we come to have some still richer and more complete experience.

What is more, owing to our power of framing general concepts and ideals, and of accumulating past and future in our present, we can focus a vast deal to one point. In such experiences, whether they come through religion, or love, or art, we may say that although we are but a system of relations, we touch the Absolute—although we are mortal, we mount to the Eternal for a moment. Only, to guard against error, we must remember that it is obviously not in reality the Absolute or the Eternal that we attain to, but only the nearest approximation to them of which we are capable.

We can therefore sum up this second part of our investigation by saying that religion, to be more than mere ritual, must involve the possibility of harmonizing the parts of the soul, of wiping out the sense of sin, of sublimating instinct, of rendering the subconscious reservoirs of energy and being available for the personal self, and of organizing the ideas of external reality into a single organized mental whole—the idea of God—capable of reacting with the personal self by interpenetration.

I may perhaps be rebuked for trying to analyse the unanalysable, for neglecting the supreme and sufficing fact of experience of God in favour of the unprofitable and impossible task of catching the infinite in an intellectual net. There are two answers to this. One is that unanalysed experience is selfish because less communicable: with that we deal later. The other is even more important: it is this. Humanity at large is *not* content with emotional experience alone, however complete and apparently satisfying: it has always demanded an intellectual formulation of the reality with which it is in contact, as well as emotional experience of it,

and so far as we can judge it will always continue to do so.

But it is further found, as matter again of general experience, that such formulations do not remain innocuous in the vacuum of pure intellect, but reverberate upon action and influence conduct. When men believe that they are surrounded with magical powers, they spend half their lives in ritual designed to affect the operations of these (wholly hypothetical) influences. When they worship a God whom they rationalize as man-like, they sacrifice a large proportion of their produce on his altars, and may even kill their fellow-creatures to placate his (again imaginary) passions. When they believe in a Divine Revelation, they think that they possess complete enlightenment on the great problems of life and death; and they will then cheerfully burn those who differ from them, or embark upon the bloodiest wars in defence of this imaginary certainty. When they worship God as absolute and as a person, they cannot help making deductions that lead them into absurdities of thought and of conduct: they deny or oppose ideas derived from a study of nature, the only actual source of knowledge, because they conflict with what they believe to be immutable truths, but are in reality conclusions drawn from false premisses; they tend to an acquiescent and obscurantist spirit in the belief that such moral and intellectual laziness is 'doing God's will', when that will is in reality their own personification of cosmic direction.

Sooner or later, false thinking brings wrong conduct. Man can perhaps get along with empirical methods and ideas which turn out on analysis to be only symbols, provided that he does not attempt difficult construction. He can have some sort of a religion, which will be some sort of a help to him, even when its so-called certitudes are only a collection of mixed metaphors, in the same way as he can

practise agriculture on a basis of mingled empiricism and superstition. But just as he is finding that he is only able to raise agricultural efficiency to its highest pitch by relying on the result of scientific method, as when he uses synthetic nitrates instead of ploughing in a leguminous crop, or just as a power-station would be very difficult to run if the staff had only symbolic ideas on the nature of electricity no closer to the real than is the symbolism of most religions, so if he does not bring scientific analysis into the intellectual side of his religion, he cannot realize religious possibilities. True that in a sense all knowledge and intellectual presentation is symbolic: but there is the world of difference between the merely analogical symbolism which takes one idea or thing as symbolic of another because there is some degree of similarity between the two and the first is more familiar, and the scientific symbolism which strives to find a scientific counter, so to speak, which shall represent particular phenomena as closely as possible, and them alone.

In religion, the danger has always been that analogy and symbolism be taken for more than they are—for scientific knowledge or even for an absolute certainty of some still higher order—and conclusions then drawn from it. The conclusions follow with full syllogistic majesty: but their feet are of clay—their premisses are false.

If we find that this is the case now, we not only may but we must endeavour to make our formulation correspond more closely with reality, must not be content to take one thing in place of another, the familiar for the unfamiliar, must set about destroying the old false formulation for fear of the further harm that it will do by its hold upon man's incurable habit of drawing conclusions.

Nor does this in any way interfere with or detract from the private and unique experiences that in the long run

are religion. They remain; but they are thus hindered from becoming draped with delusion, from leading their possessor into false courses.

We may put it in another way. Too often in the past, religious experience has been one-sided—one-or-other-sided instead of two-sided. The intellectually-inclined, the theologians, frame more or less adequate ideas of external reality, but fail in the majority of cases to set their own house in order, to organize the inner reality to react with the outer; they have theory without practice, are Dry-as-dusts. On the other hand, the emotionally-minded who are gifted besides with organizing and intuitive power, the mystics—they build up their own souls into a desired and lovely edifice, in which too they have constructed a spiritual machinery capable of viewing external realities on a new plane, under a more highly synthesized aspect; but they neglect the precise analysis of that outer reality, and so can only speak in the barest symbols and metaphors, and cannot put their hard-won knowledge into a form available for others. They have that non-communicable skill which is that of the craftsman alone as opposed to the craftsman who is also in some degree a scientist. We know good mysticism from bad, as we know good art from bad—as definitely, and as personally. And we are sure that good mysticism, like good art, is somehow of supreme, transcendent importance; but almost always it has remained like a purely symbolic art, not having for others the value which it should have or did have for the mystic himself, because not properly enchained, as the French say, with stern and immutable fact. And of the theologian we feel that he gives us the grammar, not the spirit, that he does not help us toward the supremely important act of experiencing, but only to understanding experience if we chance to have had it.

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One word on the problem of transcendence. The mystics will tell us that transcendence is a hall-mark of religion at its highest. His mode of experience transcends normal experience; things of everyday life become surcharged with new, transcendent values; he has transcended from a plane of disharmony to one of harmony. But the mystic is not alone in this. Familiar examples are best examples: and the transcendence of the lover's experience is so familiar that all mankind is divided into those who have it, those who long for it, and those who laugh at it. But the great philosopher too must mediate between the transcendent and mankind, and the true artist also, and the moralist worthy of the name.

What goes under this technical name of transcendence, therefore, is the product of some special psychological mechanism which may be at work in the most diverse spheres. If we wish to substitute one technical phrase for another, we can say that it consists in the successful attachment of what we have called absolute value to some human activity, so as to make it, for the time at least, unitary, dominant, and all-embracing. But psychologically speaking the genesis of 'absolute values' depends upon the generalizing of particular values; the raising of them to the highest possible pitch; and the putting of them and the rest of the mental organization into a relation in which they are permanently or temporarily the dominating head and front, and are connected with and gain strength and support from all the rest of the mind.

The problem of transcendence, in other words, is not one of divine inspiration, of wholly mysterious experience, but one special case of the problem of sublimation; and as such it is to be investigated by psychological science, to be understood, to be democratized, to be made more available to all who wish for it.

The most ardent enemies of traditional religion have

often professed the most transcendental type of morality. Some men are pragmatic and utilitarian in regard to Truth; by others she is worshipped as fanatically as any goddess. So some men deliberately make *mariages de convenance*; to others, the transcendence of their love is such that they precipitate themselves into what can only be described as *mariages d'inconvenance.*

I have dilated upon this at some length, because those whom we may call the religious writers on religion so often lay such stress on this question of transcendence and its special value and importance. But you do not—in the long run at least—make a thing more important by giving it an imposing title; you only give it a false exclusiveness.

Transcendence is the experiential side of what we have been describing all along: it is the finding of unity in diversity, the synthesis of discord in harmony, and in especial the finding of something of supreme value (and therefore dominant) which can be linked up with the whole extent of our mental being. Transcendence in religion differs from transcendence in art or love only in its objects. In love the discrepancy between the object and the ideal values hung round it is often so glaring as to provoke laughter from cynics, compassion from the rest. In art, the operations by which an artist turns a collection of mean and commonplace objects into a beautiful and single whole, a poet invests failure and death with authentic tragedy, or drags every day to a seat in eternity, are just as transcendent as that by which the mystic converts the relation between the warring passions of his soul and the infinite catalogue of differences which he finds around him into what he can only speak of as a divine communion, all-satisfying in itself, all-important for the conduct of his life. Science can here help religion by analysing and interpreting

phenomena such as transcendence, paring the false from the true, cutting down false claims, substituting the hopefulness of natural causation for the illogical vagaries of supernaturalism and incommunicability.

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I may perhaps be allowed to close with a few more practical aspects of the problem.

Many religious ideas and practices, as man's thought clarified itself, have proved to be unserviceable, and have been thrown on the lumber-heap, or left only with the losers in the race. It is impossible for any educated man nowadays to believe in the efficacy of magic, or of animal sacrifice; to accept the first chapter of Genesis as literally true; or to believe that God has human parts and passions. But there was a time when all these could be, and were, believed.

The time is obviously coming when a great many other ideas must be cast aside in favour of new ones. If you have followed me, you will agree that it is impossible for me and those that think like me to believe in God as a person, a ruler, to continue to speak of God as a spiritual *Being* in the ordinary way. Consequently, although the value of prayer persists in so far as it is meditative and a self-purification of the mind, yet its commonly accepted petitive value must fall to the ground; so must all idea of miracle and of direct inspiration; so must all that is involved in the ordinary materialist ideas of ritual, self-denial and worship as merely propitiation or 'acceptable incense'; so must all the externally-projected parts of the ideas concerning the ordaining of special priests; so must all notion of our having a complete, peculiar, or absolute knowledge of God, or of there being a divinely-appointed rule of conduct or a divinely-revealed belief.

On such matters, most advanced thinkers have been long in general agreement. But there is one very

important point, which, so far as I know, has been very little touched upon—chiefly, I think, because such radical thinkers have been for the most part destructive, and so have not envisaged this particular side of the question.

I hope I have been able to convince you that the scientific manner of thinking can lay the foundation for something constructive in religion: this great problem, however, remains: what sort of form or organization shall any such new-moulded religion take on itself?

We have just decided that fixed and rigid dogma is impossible, and that completeness is out of the question. Yet humanity craves for certainty and is not content to leave any factor out of the scheme of things.

To this we answer that it is here that real faith enters. We cannot know the absolute, nor have we discovered a goal for our efforts. But we have discovered a unity embracing all that we know, and a direction starting at the first moment to which our reconstructive thought can penetrate, continuing till to-day, and showing an acceleration of speed on which we may raise our hopes for the future.

We do not know all. For instance, I have studiously avoided ever mentioning the word *immortality,* since I believe that Science cannot yet profitably discuss that question. But the discovery of unity in all that has so far been studied gives us reasonable faith that its wings will reach out to cover all that we shall still be enabled to learn, while the unbroken continuity of evolutionary direction gives us the same sort of right to believe that it will continue to-morrow and on into time as we have to believe that apples will continue to fall to the earth.

The study of evolution may give us a further help. We have seen how the final steps of the highest forms of animals have been in the direction of plasticity of

organization: we see it in the rise of man from mammals, in higher as against more primitive levels of human culture, in great men as against ordinary men. There can be no doubt that its acquisition constitutes a step in evolutionary progress. Plasticity is needed in any new religion. And plasticity means tolerance, means the reduction of fixity of ritual, of convention, of dogma, of clericalism.

It is clear that, as complexity increases, need will be felt for a finer adjustment of satisfaction to mood, a more delicate adaptation of religion to the individual. A few types of ceremony satisfied primitive races: an elaborate system, fixed in essence, fluctuating in detail, has grown up in modern Christianity. But the more complex the mind, the less does it like to have to 'wait till Sunday'—the less is it satisfied with the solely biblical point of view, or the literary and musical level of Hymns A. and M.

The less also is it satisfied with the mediation of a priest. Priest (or Priest-King) is sole mediator in most savage tribes: his mediation is enormously important in the Roman Catholic Church: less so in Protestant Churches: until with the progressive raising of the spiritual and cultural level, it is perhaps possible that he may become an obstacle instead of a help. Mediators there must always be. They are the great ones—prophets and poets, heroes, philosophers, musicians, artists, and all who discover or interpret or display what for the ordinary man is hidden or difficult or rare. They mediate between the utmost attainable by man and man in the lump. As Hegel says of one group of these mediators, the artists, it is the function of their art to deliver to the domain of feeling and delight of vision all that the mind may possess of essential and transcendent Being.[1] But, with the spread of invention and the change of civilization, their mediations are becoming more and more readily

[1] Quoted from Underhill, *Essentials of Mysticism,* p. 65.

accessible to all. I can get, on the whole, more satisfactory mediation from three or four feet of properly filled bookshelf than from a dozen priests. Milton will give me doctrine if I want it, but stupendously: Wordsworth will reveal nature: Shakespeare the hearts of men: Blake can put me into a mystical, Shelley into an intellectual ecstasy, while Keats and a dozen others can open universal doors of beauty. What is more, if I have had the mediation of wise parents and good teachers, or to be so fortunate as to be enthusiastic, I find that in many things I can be my own mediator, in the same way as the Protestant found that he could read his Bible and eat the holy bread and wine for himself as well or better than the priest could do it for him.

Whatever we may say or like, it is an obvious fact that much of what is essential in religious experience, which in a simpler society was only attainable in prayer and sacrifice, communal ceremony or ritual worship, is now attainable to an increasing degree through literature, music, drama, art, and is, again, as a matter of fact, so attained by an increasing number of people who do not profess a creed or belong to a church. So that, as regards the personal, individual side of religion, many of the functions of Churches will inevitably be better performed through direct contact between the individual and the mediator—philosopher, poet, artist, or whatever he be—who provides the experience.

There remains public worship and community-religion. It is clear that whereas the Church in the Middle Ages was not only Church but also Museum of curiosities, Art-gallery and Theatre, and in large measure also took the place of our press and public libraries, now it is none of these things. There is now less reason for public worship, fewer functions for it to perform. On the other hand a religion is essentially in one aspect social, and not only

does the unity of nature demand a unity of religion, but such unity of religion would be of the highest importance as a bond of civilization and a guarantee of the federalist as against the solely nationalist ideal. Moreover, to many types of mind, and to almost all men in certain circumstances, the partaking in a public religious ceremony in common with others is of real importance. It is safe to say, therefore, that these ceremonies will continue, however much modified, and that for them a mediator or priest, even if but temporarily acting as such, will be needed. The problem is largely that of combining in public worship the religious effectiveness of the simple, the hallowed, and the universally familiar—such as inheres in many of the prayers, psalms, and hymns of the Church to-day—with the spontaneity and immediacy which, for instance, are to be found at a devotional meeting of the Society of Friends.

In any case, the new intellectual premisses once granted, the limitations imposed on human mind once understood, the important thing is to give a greater vigour and reality to religious experience itself, whether personal and private or social and public. It is just here that Science may help, where knowledge may be power. Atonement, conversion, sense of grace, ecstasy, prayer, sacrifice—the meaning and value of these and of other religious acts and experiences can be put on a proper psychological basis, they can be shorn of excrescences, and their practice take its place in normal spiritual development. That is of the essence of any religion rooted in scientific ideas—that comprehension should make practice easier and better worth while.

I am only too painfully aware of the omissions which such a cursory treatment of the subject inevitably involve. I have given you, I know, little but dry bones; but bones are the frame-work necessary before impatient life can animate a new form. If Science

can construct that form, the emotions and hopes and energies of humanity will vivify and clothe it. It is with the aid of such intellectual scaffolding that the common mind of humanity in the future, inevitably rooted in scientific conceptions as it will be, must try to raise that much-desired building, a religion common to all.

In any case, I shall be more than content if I have been able to persuade you first that the term God, just as much as the terms Energy, say, or Justice, has a real meaning and scientifically-based sense. Second, that the idea of God has and will continue to have an important biological function in man as denoting an idea, organized in a particular way, of the whole of the external reality with which he is surrounded. Thirdly, that the physical and biological sciences, in discovering the unity of matter and energy, and the direction operating in cosmic evolution, have provided a real basis for what up till now have been only theological speculations. Fourthly, that psychological science, in revealing some of the mechanism of mind, is helping us to appreciate the value of so-called mystical experience, is laying a foundation for the proper spiritual training and development of human mind, and shows us how the idea of God may be efficacious as a dominant idea in the all-important process of sublimation. And finally that, since the scientific mode of thought is of general and not merely local or temporary validity, to build a religion on its basis is to make it possible for that religion to acquire a stability, a universality, and a practical value hitherto unattained.

We are yet at the very beginning of that task, but I cannot close better than by reminding you of another biological fact of importance, that from all analogy the human species is yet near the beginning of its evolutionary career, and that man has before him vast tracts of time to set against the vastness of his tasks.

XII

SCIENCE AND HUMAN AFFAIRS

F. S. Marvin

We have been tracing so far the spread of the scientific spirit in man's outlook on the world. We saw it emerging among the Greeks, and taking the place of the earlier view, which found no order in external events, or attributed them to wilful agencies like ourselves, acting sometimes with benevolence, oftener with blind indifference or active hostility to human interests. We saw the Greek spirit humanize the world, seeking for explanations of what it saw, satisfactory to the reason of the inquiring mind; and, after an interval of a thousand years, we saw the spirit and the power of science appear again in greater vigour, till in our own day it is the dominating factor in industry, in health, in education, and even in religion.

It is clear from our survey that science, or the spirit of seeking order in events, invading human life from many angles, has already profoundly altered both the general mind and the institutions of civilized men. It has made an industrial revolution; and, looking forward, we can see that further changes in industry are inevitable from the same cause. In this sphere and in others we can predict their tendency and trace something of their coming form. In industry, however, i.e. in the application of science to the material world, the sequence has been most obvious and irresistible, and consequently our power of prediction is most complete. We may be sure, for instance, that the factory system, or mass-production, will be extended in some form to other

countries, especially in the East. We know too that means of transport and communication due to science—the giant steamship, the aeroplane and wireless—will be further extended throughout the world, and will carry further the material unification of mankind. In less developed, but yet quite clear outlines, the same process may be followed in other forms of human life. Our advance in the knowledge of physiology and of the laws of health gives us confidence that other diseases besides those already suppressed will in due course disappear. In this case as compared with industry, the factors being more complex and less subject to human will, our range of vision carries us less far, and in still higher spheres, such as government or religion, the certainty and the direction are even less assured. But over all science sheds a growing light; 'savoir afin de prévoir' is its key note.

But a great and fundamental difficulty faces us. Just as science has in recent times gained more and more influence in our lives, so men have come to believe more in, and attach a higher value to, the freedom of the spirit. In this M. Bergson is the most representative voice. Like all the philosophic thinkers of the day, he does not escape the environment of science; like Aristotle, his science is mainly biology, which looks always at the aim of living; and to him the supreme end of life is self-realization in perfect freedom. Here then we have a contradiction: science is based on discovered and ordered uniformities in nature, and leads to prediction: philosophy, at least the dominant philosophy of the day, tells us that then only have we attained our end, when we are completely free, when in the moment of action we create some new thing in the world.

The opposition seems insuperable; but for that very reason we know that we are face to face with an ultimate problem, and that both sides, opposing though they

seem, are true. On the one hand, man will undoubtedly go farther in tracing an ordered sequence of events, both in his own history and in the world; on the other hand, he is increasingly free as he becomes more civilized, that is, as mind predominates over matter. The savage is at the mercy of external forces to a degree immensely greater than is the civilized man, who can foresee their incidence, calculate their power, protect himself against them, and use them in increasing measure for his own ends. He harnesses their forces and rides the storm, though being all the time a part of the great whole of which his spirit becomes ever more clearly the driving point.

It must be sufficient here to state the paradox of which both sides command the assent of thinking and impartial men. We are concerned rather with summing up the conclusions to which it leads us, and with pointing out the right road of effort and hope in the future. Man's freedom runs no risk of injury by enlightenment as to the laws of his being and the order of his past. True progress demands their conscious realization. Even M. Bergson will grant us that.

But in the last century a mass of new sciences have arisen, dealing with the facts and the laws supposed, rightly or otherwise, to govern human life and history. They are grouped under the name of 'sociology', a term coined by Auguste Comte 100 years ago, and denoting by its mixed origin the elements of both Greek and Roman thought which have entered into its composition. We might have included in this volume a special essay on the history of sociology. But it seemed better to deal with the questions involved in a simpler and less technical manner. Moreover 'sociology', important and stimulating as its work has been, has not yet been fully naturalized among our family of sciences. It is

so great that we are rather afraid of it, so general that we are inclined to pick holes in all its conclusions. In America, where sociology has been most warmly welcomed, it has led to little fresh enlightenment, and a recent critic of the voluminous literature there produced has declared that a page of Plato or Aristotle contains more vital truth. The region to be covered is so vast and the guides speak with so many voices that the fresh inquirer may be forgiven if he thinks the course of safety points rather to tilling one small corner than attempting to survey and cultivate the whole. Of all the schools of sociology that have arisen since its foundation, the soundest and most fruitful is that which has followed Comte's lead in the land of its origin, the school of M. Durkheim in France. But we shall not speak of this work in any detail, and only consider the sort of scientific knowledge which is possible with regard to human affairs, the defects of some of the current reasoning which is offered to us as scientific, and the urgent need of applying our minds more closely to the subject.

Of what nature then is the science or ordered knowledge which we may expect to acquire with regard to human affairs and which may serve as a guide to our action? Here a distinction, first made by Comte, is useful and even necessary. He distinguished between the static and dynamic aspects of the problem: the question, on the one hand, of the conditions under which any human society can hold together and persist, and on the other, the laws of its change and, above all, of its progress or advance to a higher state. In the case of mankind, as Comte pointed out and we shall see later on, the dynamic aspect prevails increasingly over the static. It is the special quality of man, as distinguished from other animals, to strive to realize an ideal of betterment which he gains by tradition and by intercourse with his fellows,

and which becomes more and more conscious as history proceeds. On the static side man is obviously subject to the general conditions on which all life depends. The laws of physics and chemistry govern his body like all other organic and inorganic things, and, in addition to these, there are in human societies other higher rules to which all must submit if they are to live. There must for instance be some recognized authority enforcing order and checking internecine violence and spoliation; otherwise no society could live, still less enlarge itself as most societies have aimed at doing. All such conditions, whether of physical or social health, may be grouped together under the static aspect of sociology, and there is now a multitude of special sciences dealing with them. But above all this, man is a moving, evolving, progressive being, and his supreme interest is to know whence he has come, whither he is going, the past stages of his march, and how to quicken them in the future. This is the dynamic aspect of sociology, and it must prevail over the static in the sense that every higher law or state of being subsumes the lower. If we can be sure that man has a higher end, and is advancing towards it, then the fundamental statical laws, e.g. of health and order, are seen as means and not as ends in themselves. It is enough for an animal species to persist and thrive; for man it is the starting-point.

We approach then the laws, real or supposed, of progress, actual or imagined. That this is the side of sociology which, if not the most important, excites the most public interest is obvious from almost every number of a review or copy of a newspaper. We read 'The Dilemma of Civilization', 'The Decadence of the West', 'The Revolt of the Sub-man', or learn that the 'superstition of progress is the surest mark of a stationary age'. The reality of social progress is rightly judged to be

a supreme question, but the belief in it and the general agreement as to its nature have been rudely shaken by recent events.

About the middle of the last century several great thinkers had combined their voices in proclaiming the historical authenticity and future certainty of progress. Darwin followed shortly after and seemed to give a biological guarantee. The sixty years that have followed have by no means disposed either of Darwin or of a doctrine of general progress, but they have induced a more critical frame of mind. We ask now, 'In what does progress consist, and what grounds are there to believe that it will continue?' just as in the case of Darwin the biologists have inquired 'What is a variation, and how can we imagine certain variations to occur which seem so miraculously favourable to the needs of the creature?' Such questionings as these have during the last few decades covered all the ground of the great synthetic thinkers of the early nineteenth century. Then came the War. It seemed to extinguish the hopes of assured progress and speedy peace and happiness for all mankind which first shone out at the end of the eighteenth century and irradiated the century which followed.

Both the accession of criticism and the wave of pessimism were natural, but not final. It was healthy to subject the wide and glowing generalizations of Condorcet or of Comte to close examination, but it would be absurd to dismiss a widely grounded conclusion as to the growth of human society because some of its discoverers and exponents have expressed it in too unqualified a way. The growth of human society being the most extensive and complex example of evolution, the widest and longest views are needed to compass it to any purpose.

The so-called laws of social progress which have been

enunciated during the last hundred years are all of this large and stimulating order: they rest rather on broad views of human nature and history than on minute inquiry into the facts of particular societies. They are not to be dismissed on that account, or treated as unscientific, any more than we dismiss Copernicus because Tycho Brahe was the better observer and Kepler gave the proofs. There is room for both types of thinkers, and in human affairs, dependent on long-continued series of consecutive changes, the broad view leads the way. Comte's Law of the Three Stages, Spencer's Law of Increasing Heterogeneity or specialization, St. Simon's industrial in place of military organization, all contain valuable aspects of the truth; each successive thinker will criticize them afresh and bring them closer to the fuller knowledge of his own time, but that they were not conceived wildly or in vain will be apparent to any one attempting a similar survey.

Let us put beside these 'laws', or general conclusions, of the earlier thinkers, a summary statement of what appear the main lines of human advance from primitive to contemporary days, and confine ourselves to the most certain as well as the most general facts. The longer the stretch of our review, the stronger our conclusion. On one side, in remotest past, we see a savage half-human being, ignorant of the simplest general laws of nature, unaided in his struggle against external forces and hostile beasts except by his own right arm and his mother-wit, isolated in his cave or forest from other tribes of future men, ignorant of everything not met with in the daily hunt or the nightly lair. At the other end comes the modern man, with his animal senses less acute, his muscular force inferior to his savage ancestors, yet intellectually, socially, collectively so developed that the gap between him and the *Urmensch* seems even

greater than that between the *Urmensch* and the next of the Primates. And this development of the modern from the primitive man can be quite surely analysed, at least in its leading features. The modern compared with the primitive is immeasurably more powerful, more knowing both of himself and all other things, more united as a world-being and conscious of this being and of the universe in which it moves. That man has started from the one state and come to the other is certainly a historical fact: whether we call it a 'law' of progress or not depends upon the meaning we attach to that ambiguous term.

We will leave aside then the question of any 'law of progress' and only consider a few of the implications of this summary statement of the most salient and certain results of man's evolution. We leave aside the question —though we are prepared to answer it in the affirmative— whether the average of individual men has risen in knowledge, power, and goodness. We leave aside the question whether our eminent persons are as great as those of the past, and what is the prospect of any future crop of greatness. We will even leave aside for the moment the whole question of values, whether the ascertainable advance is to be considered a good thing, either for the species as a whole or for the individual. We will confine ourselves strictly to a consideration of what is implied in the social growth which we have stated, and which cannot be questioned by the most sceptical or pessimistic critic. In the course of unnumbered ages a social being has arisen, distinguished by a rapidly increasing accumulation of collective knowledge, power, and self-consciousness. It is the part of history to trace the stages and various strains in this growth. One point that must strike very sharply the attention of any student is the great acceleration of this process in recent years, i.e. since the rise of modern science in the seventeenth

century. The greatest steps, indeed, in this expansion of humanity have occurred in those recent decades since the middle of the eighteenth century which contained the synthetic thinkers some of whom we named above. The development impressed itself upon their minds because it was both new and great. It is now somewhat stale to us, and we are beginning to be conscious of other sides to the picture. But the great facts remain and have grown still greater since the early nineteenth century when they were first studied. Thus the scientific, or positive, spirit which inspired Comte's law is farther spread since his time, and in spite even of the Great War the world is further industrialized than when St. Simon foresaw the régime of industrial chiefs. Spencer's law, too, of increasing specialization is seen to be an incident in the organization of masses of men on a scientific basis for industrial and practical ends. These and other laws, therefore—generalizations which have been criticized as too sweeping and uncritical—are best understood, when duly corrected, as partial aspects of the larger truth, viz. the actual growth of humanity as a world-force through the medium of applied collective knowledge.

This view of progress, as the growth of an active common soul, or will, in mankind has been attacked, and is open to attack, on various grounds. It is said that it overlooks the supreme importance of the individual, that it elevates unduly the material results and instruments of the scientific and practical mind; above all, that it is not true—that there has been no real general growth of human feeling or common action in the world as a whole. It is beyond our scope in this short chapter to follow up such arguments, a few among the many which crowd the mind when we begin to think of science, or ordered sequence, in human affairs. But it may be possible to remove one or two more obvious misconceptions.

In the first place it must be remembered that, in tracing any law of social progress, we are, at that time and for that purpose, overlooking the individual and deliberately basing our argument on the qualities and behaviour of the greater being of which he is a member. This is no disparagement of the individual soul; but is the necessary consequence of any scientific thinking about society as a whole, into which the individuals only enter as parts. If you deny that there is any such real collective being, and that therefore we cannot reason scientifically about it, *cadit quaestio*: we must then all be treated as self-contained units, caring for and preserving our own souls alone; which is impossible. The bearing of any law of social progress, which we may be able to trace, on the character of individuals is a separate inquiry. We believe that the individual personality grows and does not wither as the society becomes larger and fuller: but we cannot pursue that topic here.

Another very common complaint against a doctrine of progress through science is based on a false evaluation of the products of scientific as compared with literary, artistic, or any other sort of thinking. There is a curious notion that it is a finer and more spiritual thing to put together a sonnet than to construct an engine, and that the latter is a base and rather degrading operation which we have to tolerate for the necessities of our lower nature, but cannot possibly conceive of as bringing us any nearer to the kingdom of heaven. The Greeks have something to answer for in this ridiculous superstition, and it was perpetuated by the literary tradition of the Renascence. All well-directed actions of the human mind belong equally to the realm of spirit, and from the point of view of social progress that should be valued most highly which is best adapted to carry out its true end, the attainment of some human good.

The last objection, that there has been no general growth of human feeling or common action, would, of course, be fatal, if true; but it is obviously not true. The most salient feature of general history is the gradual coming together of the world of mankind as one. The process has its less attractive side. It has meant the smoothing out of many interesting diversities, the spread of many vulgarizing uniformities. It has been accompanied by fierce conflicts of the stronger powers to sweep fresh tracts of the earth's surface into their net. But it has resulted in our own day in the formation of a world-organization, the League of Nations, still incomplete and expectant, but expressing for the first time in history the social will of the great majority of nations to act together and to do things making for peace and the common weal.

The League of Nations comes aptly enough into the argument, but rather as a symbol. It is the natural outcome of the unifying process which has gone on more and more rapidly in the last hundred years.[1] There are two other considerations of a philosophic kind which will fortify us in our suggested doctrine of progress, though we may base it safely in the first instance on historical grounds. Looked at philosophically, this first broad notion of progress is seen to be simply the development in time of man's special nature, as Aristotle and all other thinkers have perceived it from the Greeks onwards. Knowledge, activity with a purpose, life developed in society, these are the specially human characteristics; and social progress, as we can trace it in history, is the expansion of these qualities. And the evolution is then most clearly towards a better state, when the three factors draw together, as knowledge inspires the purposeful

[1] See Delisle Burns, *The Morality of Nations*, *The Evolution of World Peace* (Unity Series IV)

activity, and as the purposeful activity arises from the whole society and is aimed at the development of the life of all.

The other philosophical consideration, which gives corroboration, is that the science of psychology, if not new-born, has at least been most developed, and taken on its distinctive social colour, during the nineteenth century, the period when the new social will of all mankind has been most clearly shown. 'Social Psychology', the 'Psychology of Peoples', 'The Crowd', the 'Herd Mind', and similar titles of books and reviews in recent years, indicate the new direction in psychological thought since the early nineteenth century, when psychology, in its infancy, was still relying mainly on the introspection of the individual mind. The limited value of this is now generally admitted, and psychology, in its adolescence, takes its place among the social sciences and employs a comparative and historical method. Even the psycho-analyst, with his grave vagaries, is in touch with one vital truth, that our psychic states come to us from the past and depend on other beings than ourselves.

An age of psychology therefore comes to crown an age of biology; and the psychology is social, based on the manifestations of the collective mind, in the first instance of groups, and later of the whole of mankind.

The view of progress which we have suggested is a psychological one, putting the determining, characteristic factor in the mental and not the material sphere. It traces the evolution of man in his gradual ascent above his material environment and above his individual isolation, and it proclaims a real common movement towards a higher state for the race, rising above the special civilizations which have flourished and declined at various places during historic time. Science, or

collective, orderly thinking, and sympathy, or common feeling, rising at last into a conscious social will, are the leading traits in the evolution looked at from this point of view. The union of these two, broadly speaking the positive and the Christian elements, which has been coming about in recent times, is the crucial point in the human story, as it has been unrolled before us up to the present.

It is a broad and simple outline, but it has the treble advantage of being true to the dominant features in man's nature, of giving a rational account of the main currents in history and an ideal of hopeful action in the future. It would only be harmful if we used it to slur over the innumerable diversities in the concrete process or to relieve us from the task of minute and faithful inquiry into the particular facts.

A simple illustration may perhaps make clearer the nature and mutual relations of the two methods of approaching the scientific study of human affairs. We might think of the course of history, i.e. the dynamic aspect of sociology, as a long journey, of which we know in a general way the conditions and the goal. We might imagine it as a journey round the world, or, better still, up a high and distant mountain. We know from other sources the distance, the direction, the possibilities of approach. If the route were round the world, we have absolute assurance that it can be ultimately completed, for the world is round; if up a mountain, we can locate the summit by trigonometrical survey, and we know, also from *a priori* reasoning, that the powers of the travellers, if wisely used, are sufficient for the task. But this general knowledge and assurance do not exempt us from the duty of the most careful examination of the intermediate steps. If this is not done, the journey, though perfectly feasible and certain in the end to be

accomplished, may be repeatedly delayed, and will in any case be attended by losses and difficulties which preliminary study and foresight would have avoided. A sound, general scheme, fortified by accuracy and patience in detail—these are the conditions of success.

The need of sound reasoning on social problems, never so great as now, suggests examining a few of the current arguments which have been used to aggravate the unrest of the day and induce a pessimistic spirit contrary, as we believe, to ascertainable facts. Many of those who use them begin with a sincere appeal to scientific truth against the 'professors of a facile optimism', and then proceed themselves to draw all sorts of illicit conclusions from faulty premisses. The much-quoted *Untergang des Abendlands* by Spengler shall be our first example. In this the whole thesis rests upon a foundation of sand. Western Civilization, which is supposed to be in decay, is, in its scientific and international form, a new thing in the world, and no argument as to its future can be drawn from the decline of previous civilizations which were far less extensive and without the world-wide organization of the present day to hold them together. A glance at the state of the world since the War is enough to establish this. In spite of the most destructive social cataclysm in history, international activities are flourishing again, in some respects more vigorously than before, and the great areas which are most broken up—Russia and China—are precisely those parts of the world where modern scientific organization was least developed. It will be said that the downfall and sufferings of Germany and Austria are sufficient proof that science is no real defence. Exactly the opposite conclusion should be drawn. Germany held out so long and with such marvellous success owing to her scientific training and organization. She is now, in defeat and depression,

carrying on her accustomed activities in education, science, medical care, trade, &c., through the same cause, and her financial collapse, being realized as an international danger, is being dealt with internationally. The loser in the greatest of wars pursues the tenor of her course, changed in spirit no doubt, but without internal or social collapse, owing to the strength of modern organization based on science.

Spengler's main argument, like many of his subsidiary ones, is drawn from a faulty historical parallel. It is the besetting sin of a vivacious stylist writing as a historian. He sees in the second Punic War the ancient analogy between the conflict of England and Germany in our own times, forgetting that in the Great War England entered as one of a League of Nations upholding the sanctity of international law. He sees in the present state of the West signs of decadence which suggest another Decline and Fall, forgetting that the West is now only an historical term for a world-wide civilization which sprang from Mediterranean lands, but has its pillars on both sides of the Pacific and no real parallel with any of the empires or cultures of the past.

Among ourselves there is abundant pseudo-scientific writing on social themes. A recent book called the *Revolt of Civilization* is typical. Its author laments the supposed decay of vigorous manhood, and again harks back to the analogy of ancient Rome. A new race of barbarians is waiting at the gate. Who these may be is left in some doubt, as we are not breeding them ourselves.[1] But the Bolsheviks are always at hand to fill a gap in the argument.

Another favourite line of pseudo-scientific argument

[1] 'We are breeding not vigorous barbarians but a new type of sub-men, abhorred by nature and ugly as no natural product is ugly!'—Dean Inge, *Edinburgh Review*, July 1922.

is to contend that just as the Roman Empire was overwhelmed by inroads of barbarians from without, so our civilization is threatened by the uprising of a flood of 'sub-men' from below. The better-to-do classes, with a tradition of culture, have fewer children; therefore the classes below, of a supposed inferior civilization and education, will come up and take their places. But what are the known facts on this matter? It is a fact that families generally are becoming much smaller than they used to be. This tendency spreads gradually over the whole of society and over all civilized countries. At the one end of the social scale this leads to a diminution of the 'gentle' class who a hundred years ago were the undisputed leaders of society. But, on the other hand, the children of the lower middle or upper working class are being constantly improved and taking more important positions. Is there any sound reason to assume that these people are incapable in due time of acquiring the good qualities—in manners, &c.—which we associate with the old upper class? It is in any case pure ignorance and prejudice, without any foundation in fact, to sweep them all together into a class of imaginary 'sub-men'. At the other extreme of the social class we now learn (see Dr. Crookshank's chapter on 'Science and Health') that the defectives tend to extinction by inter-marriage.

Questions of heredity, the size of families, &c., are all so extremely complicated and doubtful that the mark of the scientific spirit will be to abstain from such conclusions of panic as we have quoted, and meanwhile to observe and inquire with care, patience, and an open mind. The general statistics of health, length of life, and mental capacity are all directly contrary to any theory of decadence. The conclusion to which they seem to point is that we are steadily rising to a higher level of average capacity, both physical and intellectual, from which we

may anticipate fresh eminences to appear, different no doubt from those of the past, but more suited to the demands of a democratic age.

It would be easy to multiply examples of such pseudo-scientific reasoning about human affairs as we have just given. They abound in the reviews and in popular social essays. Unfortunately, the more fallacious a thesis is, the more it is likely to gain popular credence for a while. If, like Mr. Houston Stewart Chamberlain, a writer discovers a popular historical analogy and announces it in glowing terms and with striking illustration, he is bound to find a large and credulous public. He may, like Mr. Chamberlain, announce that all the moving genius of the world belongs to one race, e.g. the Teutonic. He selects a number of cases which seem to prove his point. He suggests that in others, about which we have no sufficient knowledge, there is good reason for thinking that if we did know, they too would corroborate the conclusion. He brings out in the end a portentous doctrine which, like that of Teutonic superiority, may work immeasurable harm and embroil nations in an undying feud. The process is possible through the complexity of the facts and the impossibility of knowing everything about them. The gaps are filled up by surmises based on prejudice, or on one or another of the sociological biases which Herbert Spencer analysed for us fifty years ago.

The weakness is the obvious one of not taking pains to master all the facts and be sure of their causal relation.

It may be retorted that such a requirement precludes the drawing of the most general conclusion of all with which we began. If you have first to know all the facts, how can you be sure that there is such a thing as general progress as we defined it above? The answer is that we may, in sociology, often have better grounds for

a more general than for a more particular conclusion, as, in our suggested world-journey, we may be perfectly certain that if we start from London in a due easterly direction and keep travelling on in a straight line we shall ultimately come back to London again from the west. This does not exclude the necessity of studying with the utmost care all the intervening country and making many détours in order to arrive in the end at the object which in the general plan is sure and simple. So in the realm of public health. We know perfectly well the general conditions for the avoidance of disease, but it may be the most difficult problem to discover in a particular village the cause of an outbreak of small-pox and to take the necessary steps to exclude it.

Hence we arrive at the supreme necessity, in the application of science to human affairs, of a twofold path. We need the high or general line, based on the facts of man's nature to the broad outlines of history, and we need the careful plodding work of the investigator, establishing the facts and tracing their connexion. Neither can do without the other, neither can afford to disparage the other. No time in history has shown more clearly than the present the necessity of both, for we are overwhelmed in the practical world by a complex problem which has come upon us from want of sufficient knowledge and foresight, and the social atmosphere is infected by a want of the cheerfulness and confidence which spring from a sound general philosophy.

The complex practical problem is, of course, the reparation of the losses due to the War and the restoration of normal trade and finance. In this matter it would seem that the facts surpassed the competence of the best brains which tried to cope with them in 1918 and 1919. No one at that time foresaw the financial collapse, the colossal difficulty of carrying out in any degree what was

calmly set down as an agreed obligation in the Treaty of Versailles.

This growing complexity of human problems, without a corresponding growth of the human brain to deal with them, is perhaps the most serious obstacle which faces the onward march of mankind. It is exemplified equally on the theoretical and the practical field. The realm of science is now so vast that a small subdivision of one of its branches is enough to occupy the lifelong energies of a devoted student who, even a hundred years ago, might have hoped to acquire a competent acquaintance with the whole. And in the practical sphere the affairs of one region, which to the ancients seemed to embrace the world, are now in one department of the British Foreign Office, itself one member of the League of Nations.[1] We need not despair of the human intellect: its material organ, the brain, has demonstrably developed since prehistoric times. But the spiritual organ which must grapple with the problems of the future will not be located in any one cranium: it will be the co-operative working of many minds. Such co-operation has been shown publicly in an Age of Conference; it has been crowned recently in the newly formed committee of the League of Nations for Intellectual Work. But it exists everywhere where sound thinking on human affairs is in process, and any action such as the exclusion of German or Austrian professors from international societies is a grave mutilation of general efficiency, almost as harmful to those who inflict as to those who suffer the exclusion. To render such co-operation as effective as possible, to make the collective mind function with something of the quickness and the

[1] See Isaiah, chap. xix, where the communication of Assyria and Egypt through Palestine is treated as the consummation of World Peace.

decision of a good individual, is the highest problem of organization.

Such is the necessary method both for social studies and for social action in the modern world, but a general theory and spirit are also needed to give a moving force to the machine. Mount Everest could not be climbed without a conviction of its possibility and a hopeful determination to do it. This is given in the social sphere by the general theory of progress, based on the nature of man and the known broad facts of history. He has advanced from a lower to a higher state of existence, for we cannot believe that his recently acquired consciousness and study of this advance will operate as a brake to its further continuance. Man had been gaining science for uncounted ages before he became a conscious philosopher. Since he began to work at science consciously, the growth has been immeasurably greater. We may expect the same result to follow man's awakening to progress. The progress was a fact long ages before it was detected and its outlines described in a 'law'. The theorizing will not destroy the movement but accelerate its rate. The sadness of to-day and yesterday is but a trough between the great advancing waves, the reaction against a doctrine announced perhaps too loudly and with too little qualification by the earlier prophets. The later generation of writers, with Anatole France at their head, appreciate the greatness, are kindly to the weakness, and hopeful but less confident of the future of mankind.

In such an atmosphere a general law of progress, if it can be well founded on the facts, has a double part to play. It is the greatest generalization about man's history into which the studies of particular movements have to be fitted. If the general law is true we shall judge the smaller movements according to the degree in which they have contributed to the whole. But the law,

if we may call it a law, is also an ideal. It describes something which we have derived from a consideration of man's nature before we turned to history for its confirmation in social facts. In its ideal aspect sociology inevitably touches ethics; it becomes allied to, if not an actual branch of, a science of values. But it is its aspect as pure science which has concerned us in this volume and especially in this essay. We start from the principle that man being the social animal *par excellence*, his progress consists in the development of this quality: he becomes more social both by the extension of his solidarity with other men now living and also by the deeper sense of filiation with past generations which he gains from history. Our law is therefore primarily a law of growing sociability. But man is also the maker of organized knowledge, and the growth of science therefore becomes a leading thread in any law of progress and is connected with his increased sociability. Co-operation, enlightened by knowledge, itself a social product, produces great works of practical skill, the fruit of past effort, the foundation of a more stable society in future. Greater unity, greater knowledge, and greater power, gained by the application of knowledge,—these leading aspects of man's social evolution may be gathered in one expression as the growth of the human spirit.

We have been following in this book the function of science in determining this evolution, and we conclude that, through science and the organization which it has occasioned, our modern civilization has reached a state of extension and stability which is a new and supremely important factor for the future. We have to see to it that this more closely-knit and richer social spirit is adequately reflected in fuller and nobler personalities. This is the task of education, and herein our law of progress points an ideal for the future as well as summing up the achievements of the past.

THE 'UNITY HISTORY SCHOOLS' AND THE 'UNITY SERIES'

THE idea of these schools, which have now been held annually for five years, was first mooted at a gathering of the London Adult School Union at Jordans on the 1st of August, 1914, the day on which war was declared between Germany and Russia. The world was about to be torn in sunder by a cataclysm deplored by all and expected by very few; then was the time to turn one's thoughts to those still greater and more permanent forces which have built up the world-community of the present, imperfect as it is, but growing, as we hope, stronger in unity, and capable, as the event has proved, of surmounting even the most terrible shock which could at that time have been imagined. Mr. F. S. Marvin undertook to consider a plan for historical studies on such lines, and the first 'Unity History School' was held in August 1915 at Woodbrooke, the social and educational settlement of the Society of Friends, some four miles out of Birmingham.

The subject was 'The Unity of Western Civilization', and gave the name and general colour to all which have succeeded it. The common foundations and the essentially identical spirit of the Western civilization which sprang from Greece and Rome were clearly exhibited in their various aspects: it was not yet seen how far the same ideas would carry us in a systematic study of what may be called 'synthetic' history. But the audience of the first year were eager to continue, and one of them suggested that as we had begun by considering 'Unity'—the statical aspect of the Western world, the next step would be to turn to the conception of 'Progress'—its dynamical condition, and ask wherein it consisted, and how far it was realized in the different departments of Western activity which had been

seen in the first course to possess a certain, though an imperfect, approximation to unity of spirit.

This second course was held at the same place in the following year, August 1916. It was in many ways an advance on its predecessor. The volume following this second course, 'Progress and History', soon reached five impressions, and is used for study in several Indian universities.

An interval followed, due to the difficulties of travel and of provisioning so large a company as had assembled at Woodbrooke. But in August of 1919 the third school assembled to consider 'Recent Developments in European Thought'. This was an attempt to bring the more general treatment of the earlier volumes into closer touch with recent conditions. The period studied was limited, broadly speaking, to the last fifty years. The Great War was now over, and it seemed to form a useful *terminus ad quem* to a period which, from many points of view, starts with the Franco-Prussian War of 1870. How far, it was asked, does this limited period bear out the conclusions of the two earlier courses? The volume following this course has now reached three impressions.

Before the fourth school met, the League of Nations had been formally adopted by the victorious Powers at Versailles and the Covenant of the League had been signed by between forty and fifty nations. The course of 1920 was therefore held in conjunction with the League of Nations Union, and the volume published in the spring of 1921 under the title of 'The Evolution of World-Peace'.

The fifth course (1921) arose again by a natural suggestion from that of 1920. The Covenant of the League of Nations contains, as one of its most important sections, the clauses instituting the 'mandatory' system under which the stronger Powers in the world assume formally the responsibility of trustees towards certain of the weaker peoples. This suggested the general problem of the relations of the West towards other races and nations in various degrees of progress. This school assembled in August 1921, and the subsequent volume is now ready (July 1922) as 'Western Races and the World'.

In 1922 a course was given on 'Science and Social Progress' and the book is now in active preparation. A sketch in broad outline will be given of the history of science, especially in its relation to the contemporary social evolution. *First the historical retrospect, then the living problem, and the whole looked at from the completely human, not merely nationalist standpoint.* Such is the general plan of study which has been gradually evolved in this series.

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